EN50155 platform
Safety Remote Input Output
Mixed SIL0, SIL2, SIL4 I/O network

SATURN

Harsh environments

User manual

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1 The SATURN system

1.1 General presentation

SATURN is a platform featuring high-robustness and **availability** for safety solutions.
Easy to configure and efficient as a **railway remote I/O management solution**, this platform reduces the vehicle cabling architecture and its associated cost.

SATURN is a system based on:

- ❖ A range of I/O modules, which features

  - ✓ Input/output nodes (digital inputs, solid state relay outputs, relay outputs and analogue I/O)
  - ✓ Railway EN50155 Modules (24-120Vdc)
  - ✓ Decentralized unit, or 3U rack mounting
  - ✓ A single DIN41612 connector per node (IO + power + communication)
  - ✓ Safety integrity level (SIL0 – **SIL2 – SIL4**)

- ❖ A gateway (concentrator)

  - ✓ The concentrator manages the ring network
  - ✓ One-point communication between the platform and the end-user application
  - ✓ Gateway functions for field bus (Ethernet, MVB, CAN, CANopen, RS422/RS485…)
  - ✓ **Safety logical functions** can be integrated into the concentrator module

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❖ A Power Module

✓ The Power module delivers a clean power supply to others SATURN modules from BT
✓ Railway EN50155 Modules (24-120Vdc)
✓ Power module communicates on ring network

❖ A ring network between the concentrator and the I/O modules

✓ Two unidirectional reverse channels
✓ Redundant ring of power supply
✓ Up to 1 ms deterministic cycle for 32 IO modules
✓ 100% network operability during a line failure
✓ Safety protocol, internal and external
✓ Permanent diagnostic functions
✓ Up to 1.000 m between modules
✓ Up to 12 Mb/s for 100m repetition distance
✓ Up to 128 modules per ring

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1.2 System architecture

SATURN system is composed at minimum of:

- ✓ One Gateway
- ✓ One Power Module
- ✓ One or several I/O modules

The system can be completed with an additional concentrator and additional power modules for availability purposes (redundancy).

Each SATURN agent proposes 2 redundant power interfaces. Thus, they can be powered by 2 independent power networks that increase system availability.

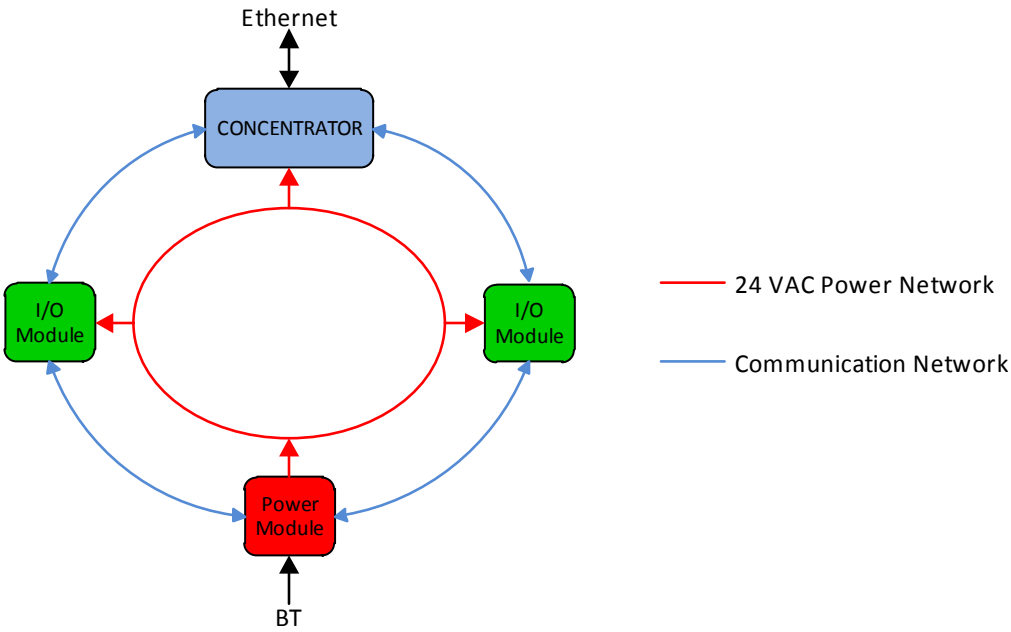
1.2.1 Ring Network Principle

The SATURN ring network fulfills two main functions:

- ✓ It ensures communications between SATURN agents (Concentrator, power modules and I/O modules),
- ✓ It delivers a clean 24VAC / 100 KHz power supply to the agents.

The communication link is a daisy chain ring that links each agent to the following one, until the last agent is connected to the first one.
The power network is a real ring that connects all agents' power inputs.

SATURN simple architecture can be schematized as follow:



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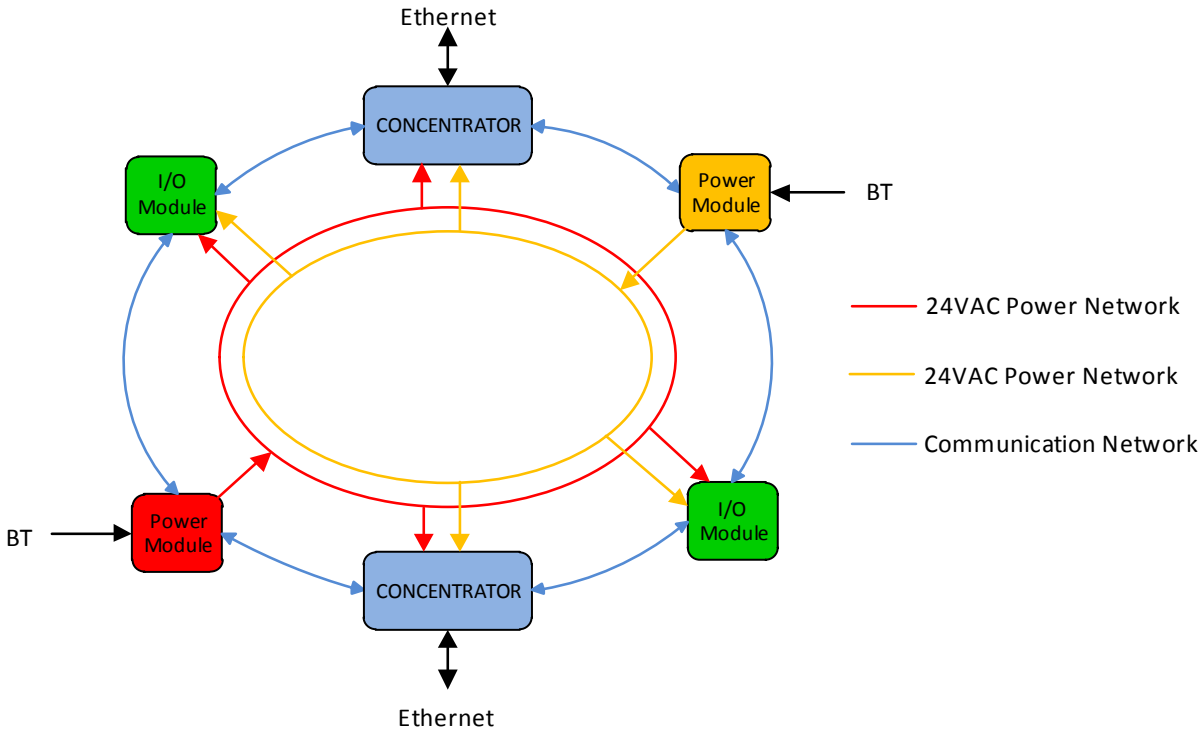
Considering additional concentrator and power modules, SATURN architecture can be schematized as follow:



The above representation highlights the fact that concentrator and I/O module are equipped with 2 communication ports and with 2 redundant power supply interfaces.

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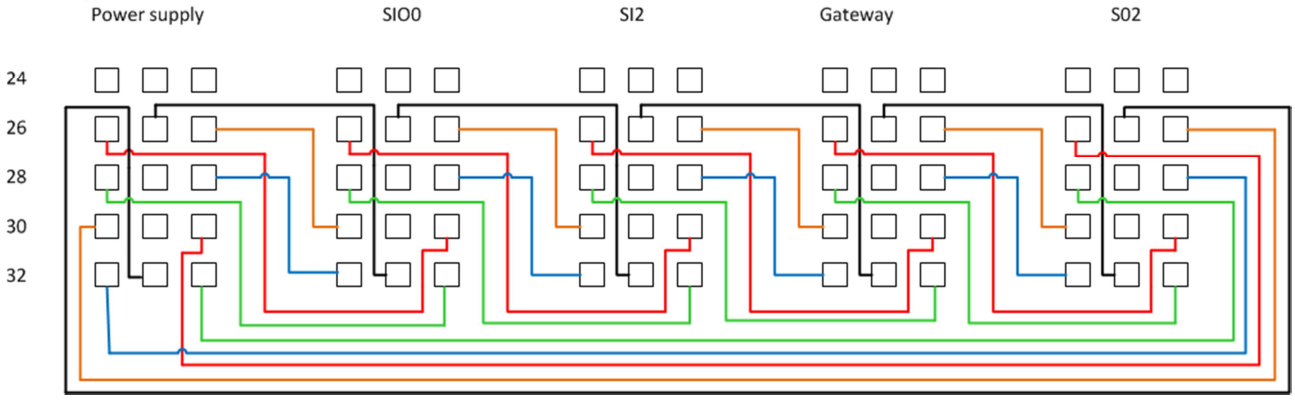
1.2.2 Ring connection

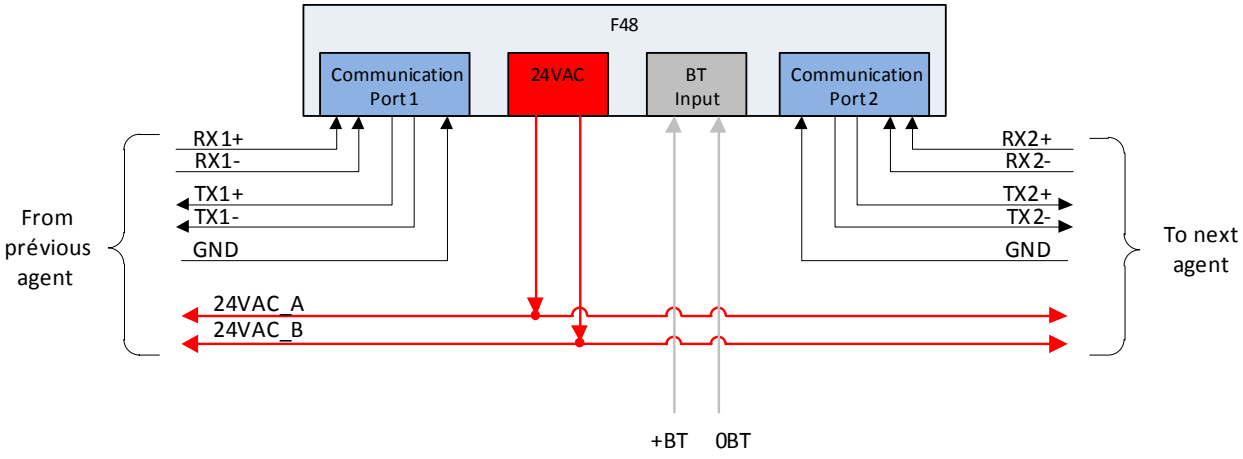
Each concentrator or I/O module shall be connected to the ring network through its single F48 connector as follow:

Note: Power port 1 and port 2 are equivalent. If a redundant power supply is not necessary, man can use any power port.

Example:



Each power module shall be connected to the ring network through its single F48 connector as follow:



The following figure gives an example of a complete system connection. It highlights the daisy chain loop of communication, and the two redundant power networks.

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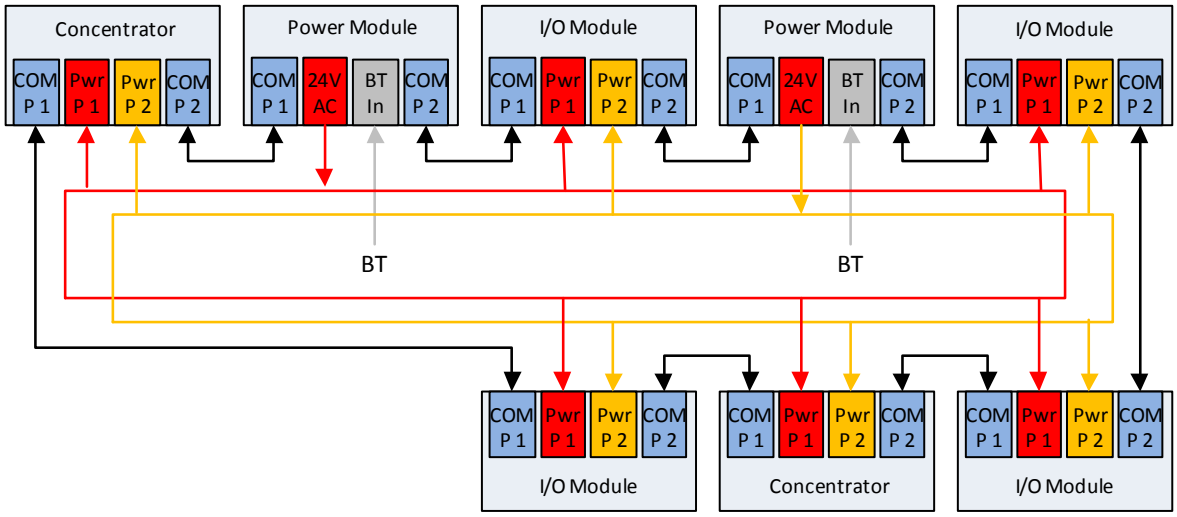
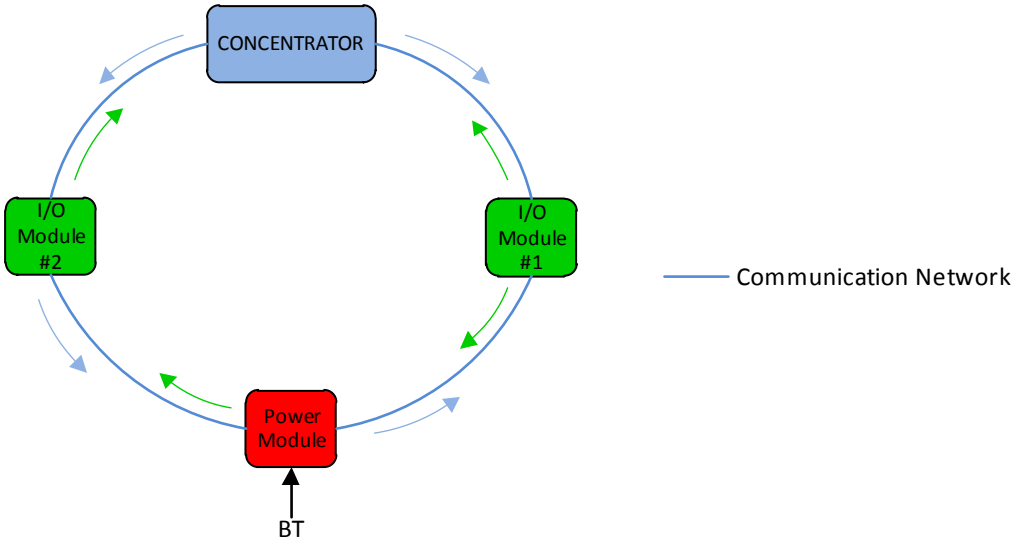


Note: Order of modules on the daisy chain loop does not matter and can be freely chosen by the system designer.
Note: The above figures do not show I/O interfaces also available on the F48 connector.

1.2.3 Communication principle

All exchanges on the ring network are managed by the concentrator that uses a specific Master/Slave protocol. In order to increase system availability, all messages are sent systematically on both directions on the communication loop.
On the following figure, the concentrator addresses the I/O module #1 with a request message (in blue) that is sent on both concentrator's communication ports. Both messages reach the I/O module #1 (one message on each communication port). The I/O module computes its answer message (in green), also sent on both communication ports.



In order to ensure message propagation from nodes to nodes, each agent will copy with low latency any incoming frames on one communication port to its other port. In the same time, each agent shall be able to send on the communication network its own messages. All of this is possible with the following logical block that equips all agents:

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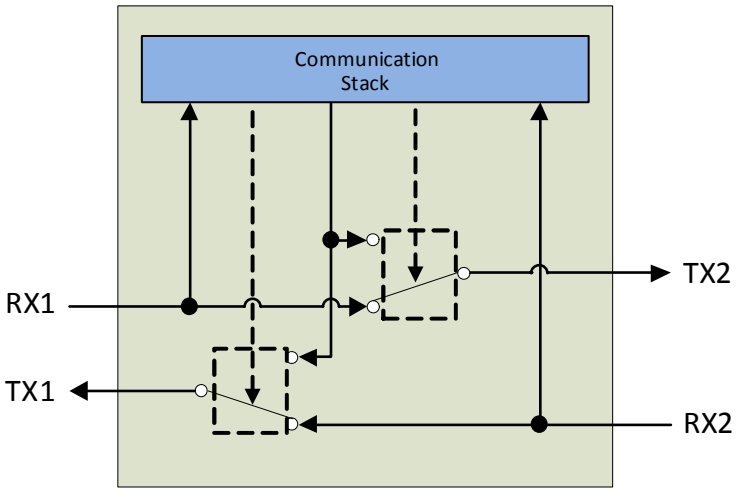

Both incoming frames on RX1 and RX2 are decoded and managed by the communication stack that also computes the outgoing frames. In the same time, incoming frames are copied to the other port. Internal logical switches are managed by the communication stack in such a way it can emit messages on the communication network without losing any incoming frame.

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1.2.4 System configuration

The SATURN concept provides the system designer with several parameters that allows matching as much as possible end users' needs:

- ✓ The number and the type of I/O to be managed by the system

The system designer can link on the same communication network up to 128 agents (I/O module or power module) in addition with one or two concentrator. The I/O modules can be of any type and any order. The only restriction applies on the global consumption of the agents powered by a single power network. System designer shall ensure that the sum of the maximal power consumption of each agent (I/O module or concentrator) linked on the same power network is less than the maximal available power driven by the power module (refer to specific sections of this document for modules maximal power consumption and power module available power.
Thus, system designer shall implement as many power loop (and related power module) as necessary.

- ✓ Boolean Equations

The concentrator can be configured with automatic output treatments. Boolean equations can be defined to activate automatically output according to operations of other platform I/O. The result of this equation is computed at each cycle then the concentrator updates the outputs. The available operators are 'AND', OR', 'NOT' and 'XOR'.

- ✓ The communication speed

Communication speed on the communication network can be configured from 50Kbits/s to 12MBits/s. A 12 MBits/s communication speed is suitable for communications on copper twisted pair up to 100m long. If a longer distance is required between 2 consecutive agents, communication speed shall be lowered.

- ✓ The cycle time

Communication on the communication network is based on a cyclic scheme: at each cycle, the concentrator updates all the outputs and gathers all the inputs of all the I/O modules. In other words, the cycle time can be seen as the maximum latency before an input change is seen by the concentrator, or an output is updated.
It can be set as low as required for system performances from 1ms up to 255ms. Nevertheless, the cycle time shall never be set lower than a minimum time that depends on:

- ✓ The number and the type of agents on the communication network
- ✓ The communication speed.

As an order of magnitude, SATURN system accepts the following minimum cycle time for a communication speed of 12MBits/s:

- ✓ 1 ms for 32 SIL 0 I/O modules
- ✓ 10ms for 75 SIL2 or SIL4 I/O modules

Each parameter (number and type of module, cycle time, communication speed) are highly dependent of the 2 other parameters. All 3 parameters shall meet the following equation to ensure the system good behavior:

$$0.7 \times Tcyc > \frac{Size \times 10}{Baud}$$

Equation 1

With:
Tcyc: The cycle time in seconds
Baud: The communication baudrate in bits per second (b/s)
Size: The amount of bytes to be exchanged on the network at each cycle and defined as:

Size = 12 + SIL24_MOD x 24 + SIL0_MOD x 15 + SIL24_OUT x 24 + SIL0_OUT x 15

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With:
SIL24_MOD: Number of SIL 2 or SIL 4 I/O modules
SIL0_MOD: Number of SIL 0 modules (including power modules)
SIL24_OUT: Number of SIL 2 or SIL 4 modules that manage digital outputs
SIL0_OUT: Number SIL 0 modules that manage digital outputs

Note: The installation workbench will help you defining the minimum allowable cycle time for your system (see §2).

1.2.5 Concentrator Operations

The concentrator fulfills 3 kinds of operations:

- ✓ It ensures the SATURN communication network management (gather inputs, pilot outputs, diagnostic network).
- ✓ It ensures gateway with an upper system from Ethernet ports (get commands, return input states, return input/output and network status, rise alarms). Default protocol on Ethernet interfaces is EIP. Nevertheless, any Ethernet standard protocol can be implemented, or customer proprietary protocol can be developed from specification.
- ✓ It computes SATURN outputs states from SATURN inputs and Ethernet commands, on the basis of user-defined boolean equations. Refer to §2.3.3 & §3.3 for additional information explaining how to setup the boolean equations.

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1.3 Availability

SATURN concept proposes intrinsic and optional features that increase system availability:

- ✓ Communication redundancy

Each message on the communication network is sent twice. The addressed module will process the first message received and will discard the other one. It means that, in case of communication network failure, 100% functionalities are ensured. In the same way, in case of module failure, the only functionalities of the module are lost and the rest of the system will be kept in full operation.
In addition, all information (namely input and output states) is systematically exchanged at each communication cycle, even if no state change has to be notified. It means that even in case of severe communication failure, all information will be available during next communication cycle.

- ✓ Redundant power supply

All SATURN modules can be powered by two independent power networks. Thus, in case of failure of the power network or the power module itself, system is still fully operational, without loss of service.

- ✓ Redundant supervisor

SATURN concept accepts an optional second concentrator on the communication network. In case of failure of one of them, the remaining one is able to handle the network in one cycle, without loss of service.

- ✓ Redundant I/O module

Inputs and outputs of I/O modules are designed in such a way it is possible to pilot the same actuator or to read the same input with two different I/O modules. Thus, if needed by the final application, it is possible to implement redundant I/O module to increase the system availability.

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1.4 Safety

A SATURN platform can manage inputs and outputs with a Safety Integrity Level (SIL) 0, 2 or 4. The related managed fear events are:

- ✓ A safety output relay is closed while it is expected to be not (open state ensured with SIL 2 or SIL 4)
- ✓ A safety input is declared active (logical '1') while it is actually not

All SATURN agents are designed and certified against EN50126, EN50128, EN61508 and EN50129 requirement to reach individually a Safety Integrity Level 0, 2 or 4.

A SATURN platform can be built from modules with different SIL. Nevertheless, since the concentrator acts as the master of the communication network, the complete system is not entitled to a SIL higher than the concentrator's SIL. For example, a system that embeds SIL 0, SIL 2 and SIL 4 I/O modules, with a SIL 2 concentrator is entitled to a SIL 2 certification for I/O managed by SIL 2 and SIL 4 I/O modules, and a SIL 0 certification for I/O managed by SIL 0 I/O modules.

SATURN platform SIL relies on compliance against EN50126, EN50128 and 50129 standards, but also on compliance of the communication network protocol against EN50159-2. It also relies on the precise identification and the differentiation of identical safety modules (SIL 2 or SIL 4). This is performed from an identification chip, delivered by Leroy Automation or Clearsy, that has to be wired on the F48 connector's counterpart (see §4.4 for identification chip cabling requirements).

Safety modules can be either in normal mode or in fallback mode. The fallback mode is default mode and is the most restrictive state of the module. In this state, inputs and outputs of the module are in restrictive position. Since expected states of safety I/O are controlled by the concentrator, in case of complete loss of communication, safety modules enter fallback mode. Nevertheless, since all information is exchanged at each communication cycle (see §1.3), communication loss may not be critical for safety application during few cycle. Thus, the amount of communication cycle lost before to enter fallback mode can be user defined for each safety module (see §2.3.2).

1.5 Diagnostic

The concentrator of a SATURN platform performs permanently diagnostic operations on the communication network and on the connected agents.

At each cycle, it computes

- ✓ the communication network status (missing modules, network segments malfunction)
- ✓ health of redundant power network (if present)
- ✓ module health (consumed power, internal temperature, input/output malfunction)

All diagnostic information is available on the client network from the Ethernet link.

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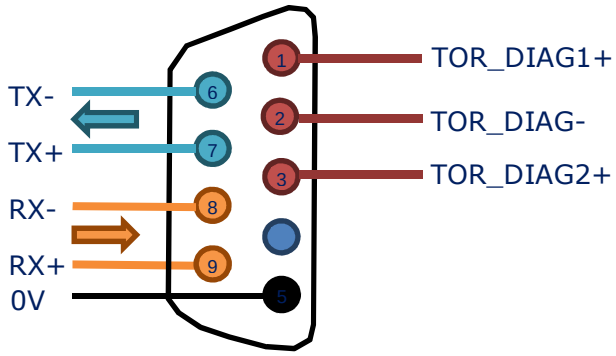
1.6 Maintenance

Each module proposes a local maintenance interface (female SUBD 9 pins connector) with:

- ✓ a serial link RS485 ; 115200 bauds ; 8 data, 1 start, 1 stop, no parity
- ✓ two general purpose digital outputs



Signal name	Definition	Electrical Levels
TX+ / TX-	RS485 Transmission lines. Format reserved for factory operations.	RS485
RX+ / RX-	RS485 Reception lines. Format reserved for factory operations.	RS485
0V	Reference ground for RS485 interface.	-
TOR_DIAG1+ / TOR_DIAG1-	General purpose open collector outputs. Refer to specific module section for meaning.	160V / 100mA
TOR_DIAG-	Reference ground for open collector outputs.	-

The following sections describe all messages that can be sent on this maintenance interface.

1.6.1 SO2

Diagnostic

Message	meaning
[Debug] La température vaut : %d °C	Temperature measured
[DEBUG] La tension g_MES_12V vaut : %4.2fV	12V Power measured
[DEBUG] La tension g_MES_1V2 vaut : %4.2fV	1.2V Power measured
[DEBUG] La tension g_MES_48A vaut : %4.2fV	48V PowerA measured
[DEBUG] La tension g_MES_48B vaut : %4.2fV	48V PowerB measured
[DEBUG] La tension g_MES_I24 vaut : %4.2fV	I24 Power measured
[DEBUG] La tension g_MES_U24 vaut : %4.2fV	24V Power measured
[DEBUG] Le MAC vaut : 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X	MAC address read on the Dallas chip
[DEBUG] L'IID vaut : 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X	IDD address stored in the FPGA

Other information

Message de maintenance	significations
[INFO] WD externe OK	Test on external watchdog OK
reboot par XXXX	Kind of reboot

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Message de maintenance	significations
SATURN SO2 Version Logicielle : %d.%d Version Matérielle : %c%c Checksum : 0x%.4x	Information about versions and checksum

Errors

Message de maintenance	significations
[Erreurs_CriticalCRC] %s	Wrong software CRC test
[Erreurs_SecuredBoolean] %s	Error on secured boolean
[Erreurs_SecuredWD] %s	Error during external watchdog test
[Erreurs_Critical12VRel] %s	Error during relays watchdog test
Init :: Relais_VerifDemarrage : Relais XPY collé/HS	Error on relays during initial tests
[INFO] Relais_Verif : Relais XPY colle/HS	Error detected on relays

1.6.2 SI2

Diagnostic

Message	meaning
[Debug] La température vaut : %d °C	Temperature measured
[DEBUG] La tension g_MES_1V2 vaut : %4.2fV	1.2V Power measured
[DEBUG] La tension g_MES_48A vaut : %4.2fV	48V PowerA measured
[DEBUG] La tension g_MES_48B vaut : %4.2fV	48V PowerB measured
[DEBUG] La tension g_MES_I24 vaut : %4.2fV	I24 Power measured
[DEBUG] La tension g_MES_U24 vaut : %4.2fV	24V Power measured
[DEBUG] Le MAC vaut : 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X	MAC address read on the Dallas chip
[DEBUG] L'IID vaut : 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X	IDD address stored in the FPGA

Other information

Message de maintenance	significations
[INFO] WD externe OK	Test on external watchdog OK
reboot par XXXX	Kind of reboot
SATURN SI2 Version Logicielle : %d.%d Version Matérielle : %c%c Checksum : 0x%.4x	Information about versions and checksum

Errors

Message de maintenance	significations
[Erreurs_CriticalCRC] %s	Wrong software CRC test
[Erreurs_SecuredBoolean] %s	Error on secured boolean
[Erreurs_SecuredWD] %s	Error during external watchdog test

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1.6.3 CO2

Diagnostic

Message	meaning
[Debug] La température vaut : %d °C	Temperature measured
[DEBUG] La tension g_MES_1V2 vaut : %4.2fV	1.2V Power measured
[DEBUG] La tension g_MES_48A vaut : %4.2fV	48V PowerA measured
[DEBUG] La tension g_MES_48B vaut : %4.2fV	48V PowerB measured
[DEBUG] La tension g_MES_I24 vaut : %4.2fV	I24 Power measured
[DEBUG] La tension g_MES_U24 vaut : %4.2fV	24V Power measured
[DEBUG] Le MAC vaut : 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X	MAC address read on the Dallas chip

Other information

Message de maintenance	significations
[INFO] WD externe OK	Test on external watchdog OK
reboot par XXXX	Kind of reboot
SATURN CO2 Version Logicielle : %d.%d Version Matérielle : %c%c Checksum : 0x%.4x	Information about versions and checksum
[info] Position introuvable	CO2 position not found in the configuration
[info] Le Nombre de concentrateur est incorrect	Problem between the number of CO2 on the network and the SID defined in the configuration (please refer to §3.1)
[info] Mauvais SID	SID in the configuration doesn't verify the exported constraints described in §3.1)
[info] Découverte du réseau : Le %d ieme agent a une IID différent : 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X au lieu de \n 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X 0x%2X	One module has a different IID compared to the information stored in the configuration
[info] Le LANSCAN est terminé et valide	Information about LANSCAN results : OK
[info] Le LANSCAN est terminé et invalide, tous les agents n'ont pas été couverts	Information about LANSCAN results : NOK (problem on number of module discovered)
[info] Le LANSCAN est terminé : Le réseau est ouvert au niveau du %d ième agent droit/gauche	Information about LANSCAN results : NOK network opened
[info] Le LANSCAN est terminé et invalide : Le réseau n'est pas cohérent avec la configuration au niveau du %d ième agent	Information about LANSCAN results : NOK one module doesn't match the configuration

Configuration

Message de maintenance	significations
Tests_VerifCRCSecu : FLASH_AdresseInvariants : passage de la flash externe à l'interne	Error on internal configuration : configuration on external memory retrieve
Tests_VerifCRCSecu : FLASH_AdresseInvariants : rien sur la flash interne ni externe -> reformat	Error on internal and external configuration. Soft set in security
[Erreur] Erreur lors de la synchronisation	Error during communication between CO2 and the CO2 configuration workbench
[Erreur] Système non synchronise	Error during communication between CO2 and the CO2 configuration workbench
[Erreur] [VIE_MAINTENANCE] Systeme non synchronise	Error during communication between CO2 and the CO2 configuration workbench

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Message de maintenance	significations
[Erreur] Erreur de CRC	Error in the configuration data (CRC)
[Erreur] Nb agents > 128	Error in the configuration data (number of module (> 128))
[Erreur] Nb IO de l'agent %d inférieure à 0 ou supérieure à 16	Error in the configuration data (number of IO in a module (> 16))
[Erreur] Le TID de l'agent %d = 0xFF	Error in the configuration data (TID = 0xFF)
[Erreur] Le TID du concentrateur agent %d != 0xF0	Error in the configuration data (TID of a CO2 different from 0xF0)
[Erreur] Le SID de l'agent %d = 0xFFFFFF	Error in the configuration data (SID set to 0xFFFFFF (reserved))
[Erreur] Mauvais format SID conc	Error in the configuration data (SID of CO2 doesn't verify the exported constraints §3.1)
[Erreur] Le CNF_REQ de l'agent %d = 0	Error in the configuration data (CNF_REQ value = 0 (reserved))
[Erreur] Le CNF_CYC de l'agent %d = 0	Error in the configuration data (CNF_CYC value = 0 (reserved))
[Erreur] Débit incorrect	Error in the configuration data (wrong baudrate)

Errors

Message de maintenance	significations
[Erreurs_CriticalCRC] %s	Wrong software CRC test
[Erreurs_SecuredBoolean] %s	Error on secured boolean
[Erreurs_SecuredWD] %s	Error during external watchdog test

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1.7 Catalog

Currently (March 2015), the Saturn product range includes the following references:

Part number	Specifications
P SAT 011 001	BT 72 Power Module – Standalone mounting
P SAT 021 001	BT 72 Power Module – 3U Rack mounting
P SAT 212 010	Concentrator with EIP Protocol – SIL 2 – Standalone mounting
P SAT 222 010	Concentrator with EIP Protocol – SIL 2 – 3U Rack mounting
P SAT 213 001	4 digital outputs – SIL 2 - Standalone mounting
P SAT 223 001	4 digital outputs – SIL 2 – 3U Rack mounting
P SAT 213 002	4 digital inputs – SIL 2 - Standalone mounting
P SAT 223 002	4 digital inputs – SIL 2 – 3U Rack mounting
P SAT 013 001	12 digital inputs/outputs+4 outputs – SIL 0 - Standalone mounting
P SAT 023 001	12 digital inputs/outputs+4 outputs – SIL 0 - 3U Rack mounting
P SAT 4X8 001	Identification chip for SIL2 / SIL4 modules

The following references are planned to available by end-2015:

Part number	Specifications
P SAT 412 010	Concentrator with EIP Protocol – SIL 4 – Standalone mounting
P SAT 422 010	Concentrator with EIP Protocol – SIL 4 – 3U Rack mounting
P SAT 413 001	2 digital outputs – SIL 4 - Standalone mounting
P SAT 423 001	2 digital outputs – SIL 4 – 3U Rack mounting
P SAT 413 002	4 digital inputs – SIL 4 - Standalone mounting
P SAT 423 002	4 digital inputs – SIL 4 – 3U Rack mounting

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2 The SATURN workbench

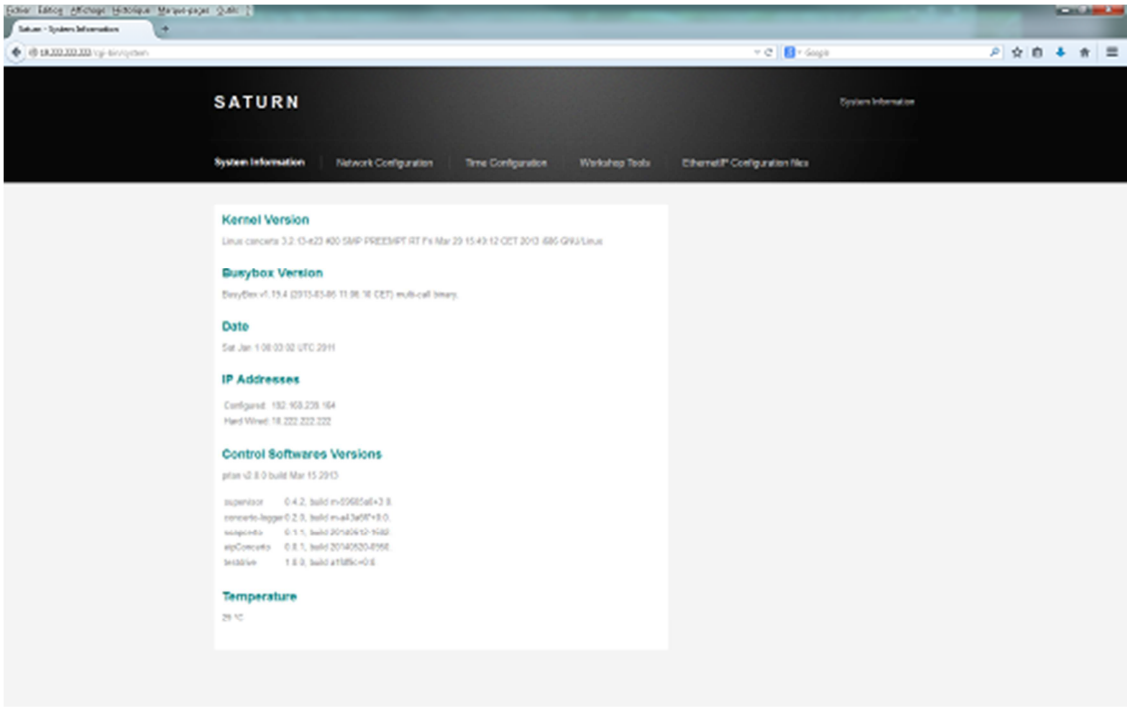
A SATURN platform can be configured and monitored from an integrated PC tool. The software is available for download from any concentrator Ethernet port.
SATURN workbench tool run on PC with Windows XP, Windows 7 or Windows 8. Adobe Air version of the workbench tool can also be run on MAC OS.

The workbench can be used in connected or unconnected mode. In unconnected mode, a SATURN platform is not needed, and only the installation tab is available. The workbench can be used to plan an installation. In connected mode, the PC shall be connected to a concentrator. In this latter mode, all workbench functionalities are available.

2.1 Installation

At first commissioning, if the workbench is not yet installed on your PC, run the following procedure:

- ✓ Connect any concentrator to a PC from an Ethernet cable (connection can be direct or through a switch).
- ✓ Power up the concentrator.
- ✓ From the PC web browser, connect to the default factory IP address: 10.222.222.222, or to the specific concentrator's IP address if known. (take care that the PC network card is configured in accordance with the used IP address.
- ✓ The following screen is reached:



- ✓ Select the 'Workshop Tools' tab to get the following screen

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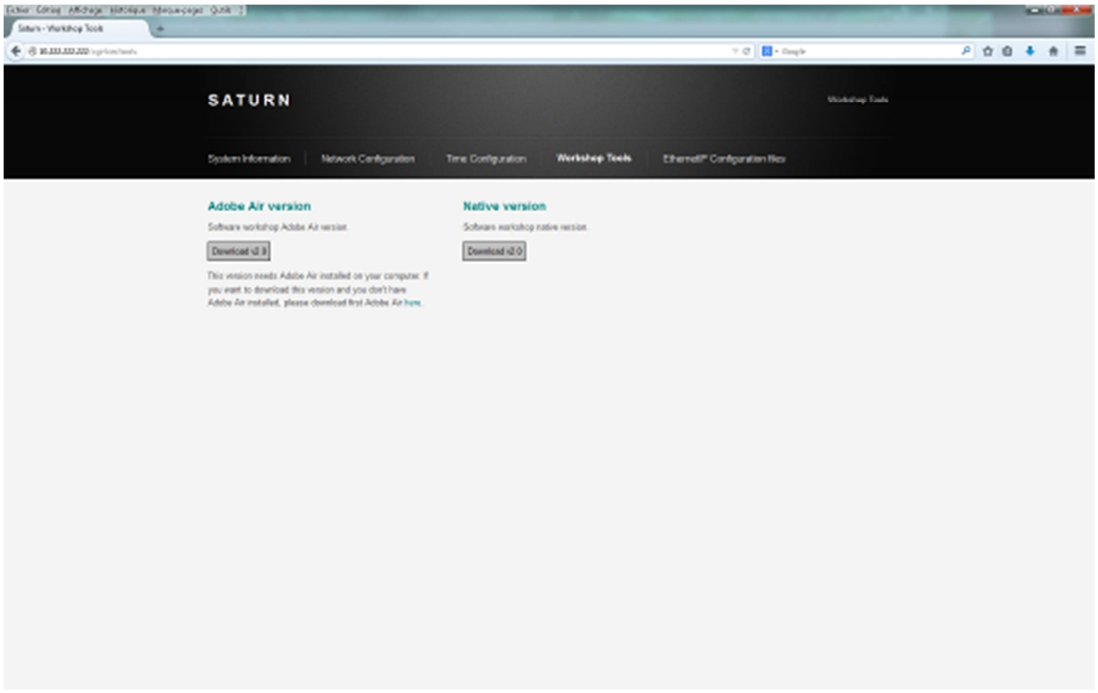

- ✓ Download one of both available version:
  - o Adobe Air Version (requires that Adobe Air is installed on the PC)
    Run the downloaded file: atelierLogiciel_v2.air and follow installation instructions

  - o Native version
    Run the downloaded file: atelierLogiciel_v2.exe and select a directory for install. The workbench is launched automatically after install is complete

2.2 CO2 configuration

In order to use the symbolic view of the SATURN work bench, the CO2 Bridge (which make the real time diagnostic of the platform) has to be load with the configuration files "lan.cfg".

1. You must activate the remote access on the Gateway:
   a. Connect on CO2 webpage @:10.222.222.222 (cf previous §)
   b. Activate the remote access on the concerning tab
2. Use file transfer software (like winSCP for example)
3. Connect the CO2 with the PC (on Ethernet CO2 port)
4. Make sure that you have a compatible IP address on PC (192.168.0.1 for example, if the default CO2 address was not changed).
5. Configure a connection with the following parameters:
   a. *File Protocol* : SCP
   b. *Host name* : CO2 IP address (default : 192.168.0.42)
   c. *Port* : 22
   d. *User name* : root
   e. *Password* : 00000
6. Use file explorer to go to ./rw/etc/Saturn/
7. Place the configuration file named "lan.cfg" in this file
8. Then restart the CO2.

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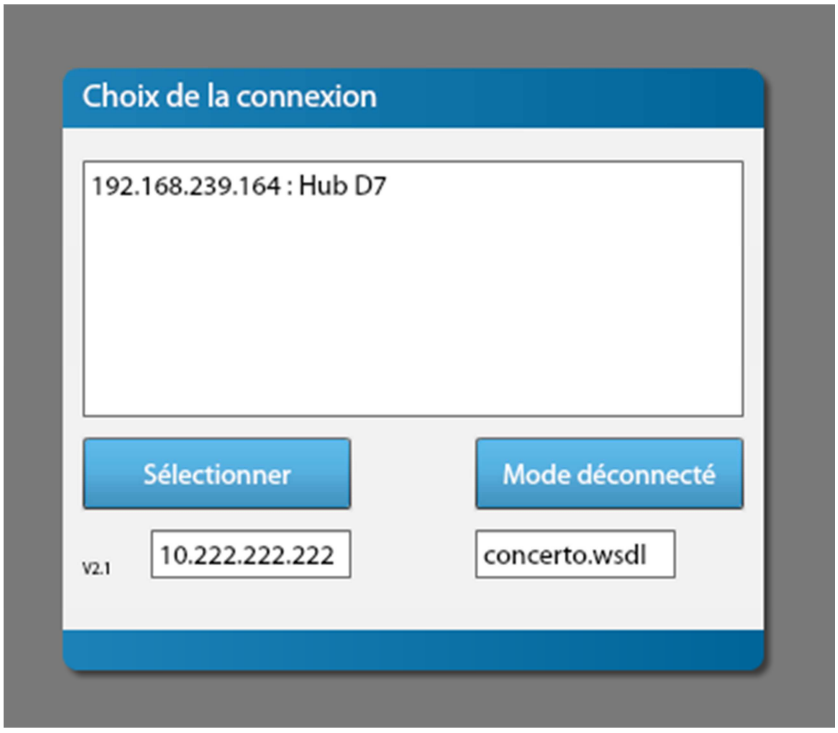
2.3 Functions

Once run, the workbench proposes the following screen:



The windows displays the IP address of all the concentrators identified on the network. Select the appropriate concentrator and click 'Connect', or click 'Unconnected Mode' if a connection to a concentrator is not required.

The top left corner of the screen proposes 6 tabs dedicated to specific functions.

2.3.1 Symbolic view

The symbolic view gives an overview of the overall system status. It represents on a single view all the modules that compose the system. Each module type is identified by a specific color:

- ✓ Light blue for SO2
- ✓ Dark blue for SI2
- ✓ Green for SIO0
- ✓ Purple for power module
- ✓ Grey for concentrator

The following figure is an example of a SATURN platform composed of 70 input/output modules, 1 power module and 1 concentrator.

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When a module is missing or is in fault, it is displayed in red instead of its natural color.
Each I/O module icon includes specific color boxes whose codes are as follow:

- ✓ White for a logical '0',
- ✓ Green for a logical '1',
- ✓ Red for a input/output in fault.

Each communication network segment is also represented with a color:

- ✓ Green when the segment is fully operational,
- ✓ Red when the segment is in fault.

When the operator moves the cursor over one module's icon, a popup window gives additional information about that specific module.

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2.3.2 Installation

The installation view is available in connected or unconnected mode. It allows an operator to configure a SATURN platform defining:

- ✓ The number and type of modules,
- ✓ The communication cycle time and baudrate,
- ✓ The specific parameters of each I/O module

The overall installation view is given here after.

Each module possible location is represented by a ghost icon. The very first ghost icon at the upper left corner represents the concentrator to which the PC is connected. Other ghost icon can be configured to be any module type.
A double click on a ghost location or on a used location opens a popup window whose fields are specific to the module type.

Note: The two fields 'Label' and 'Location' are common to all module type popup. They are free text fields and allow the operator recording some additional information related to the module (location in train, main function …)
Note: For all safety modules, private network MAC and SID fields recall for information the value of the identification chip attached to the module, and affected SID used for safety communication (refer to the SATURN protocol specification for additional information on SID usage).

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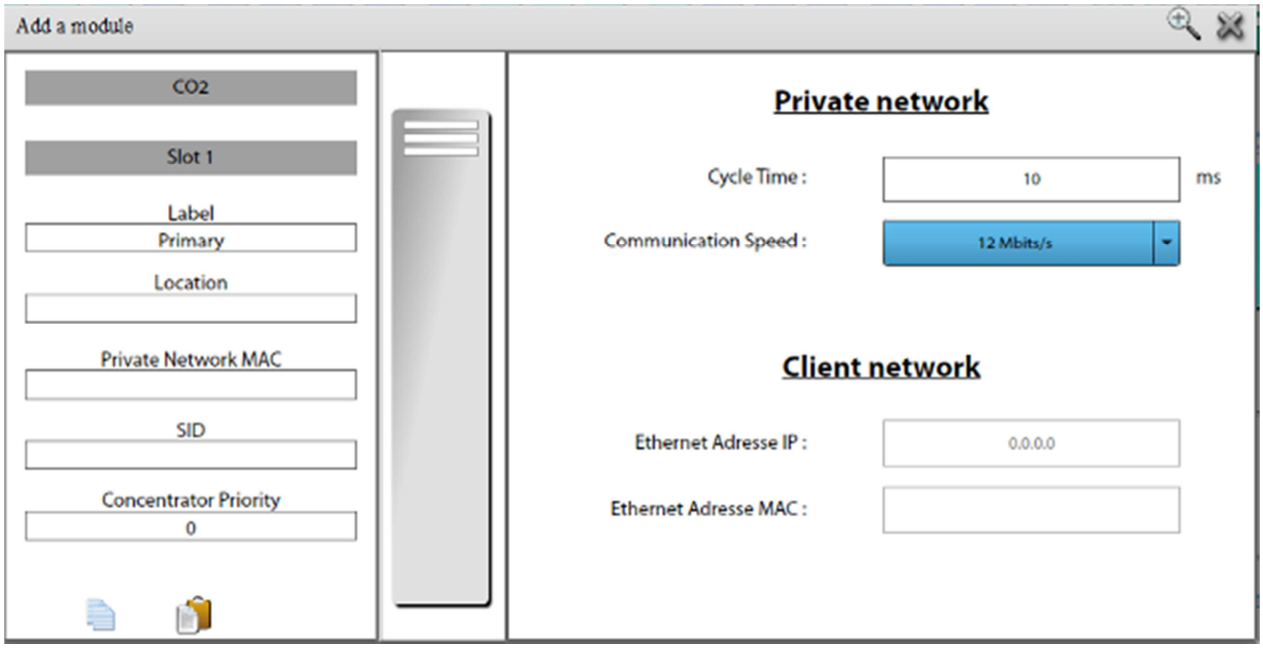
2.3.2.1 Concentrator

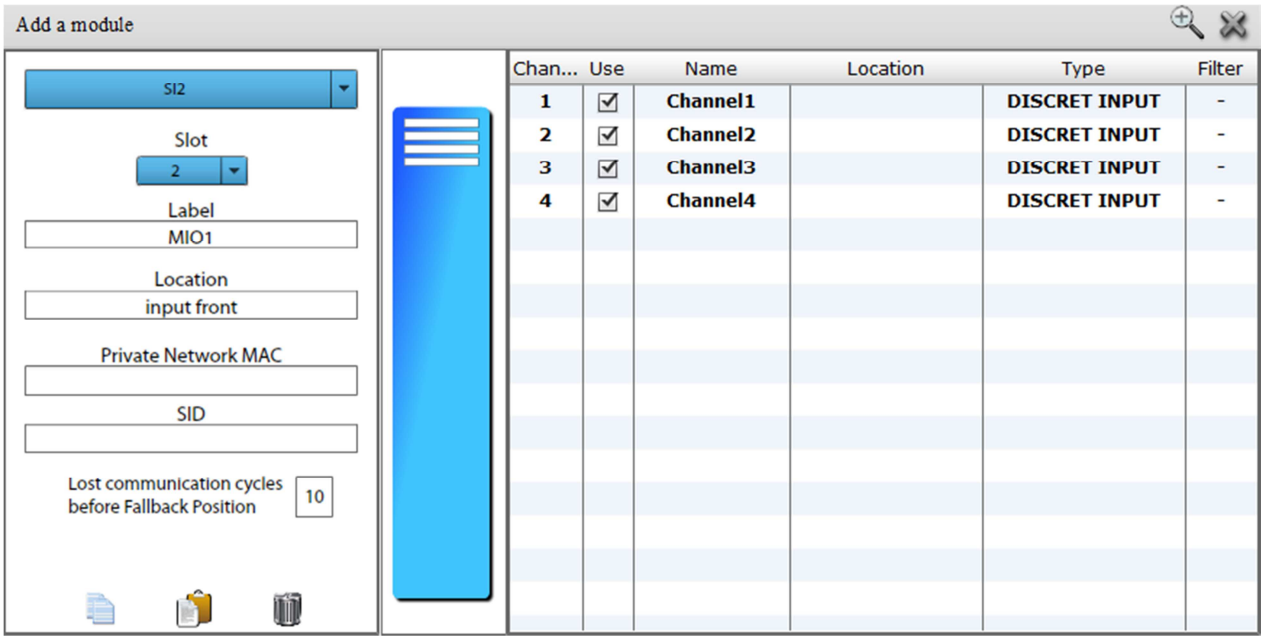
The following concentrator popup window allows configuring the cycle time and the communication speed.



When setting a new value for the cycle time or the communication speed, if Equation 1 is no more met, a message warns the user and the gives the maximal/minimal authorized value for the modified parameter.

2.3.2.2 SI2

The following popup window allows configuring a SI2 module.



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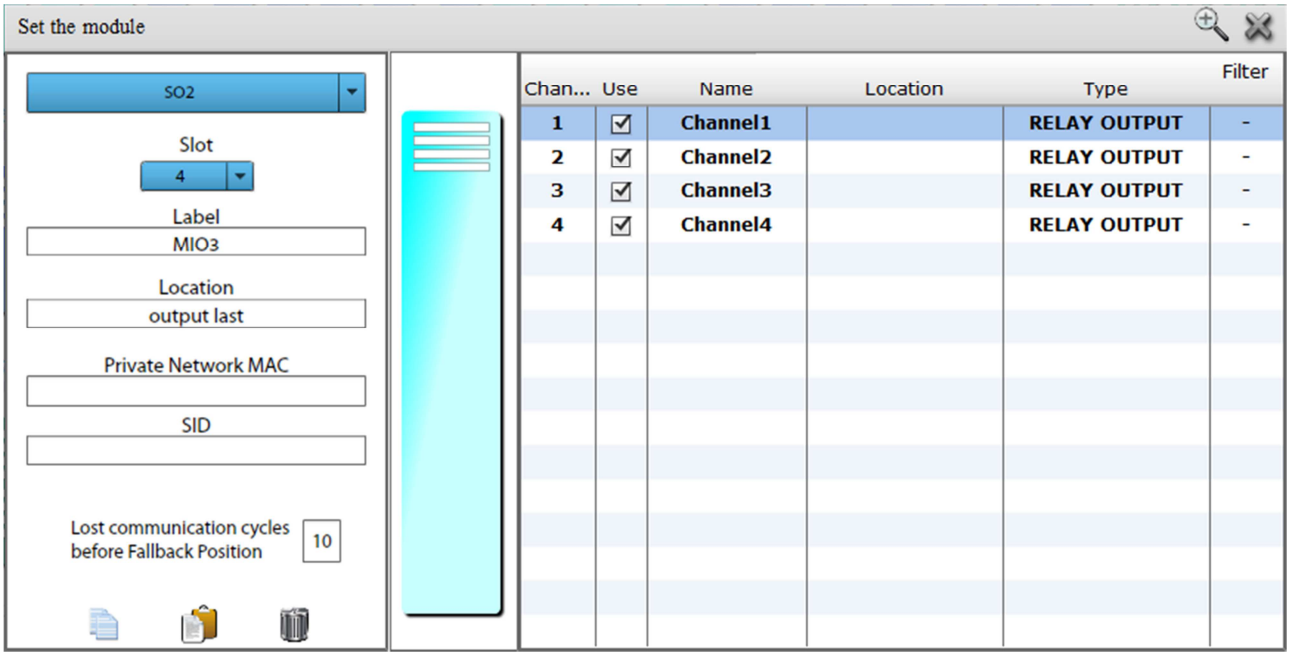
The tick box column allows selecting which input is used or not. Name and Location columns are free text fields that can be used to record additional information related to the input channel.
The field 'Lost communication cycles before Fallback position' allows configuring how many cycle time without communication is allowed by the module before to enter fallback mode (see §1.4).

2.3.2.3 SO2

The following popup window allows configuring a SO2 module.



The tick box column allows selecting which output is used or not. Name and Location columns are free text fields that can be used to record additional information related to the output channel.
The field 'Lost communication cycles before Fallback position' allows configuring how many cycle time without communication is allowed by the module before to enter fallback mode (see §1.4).

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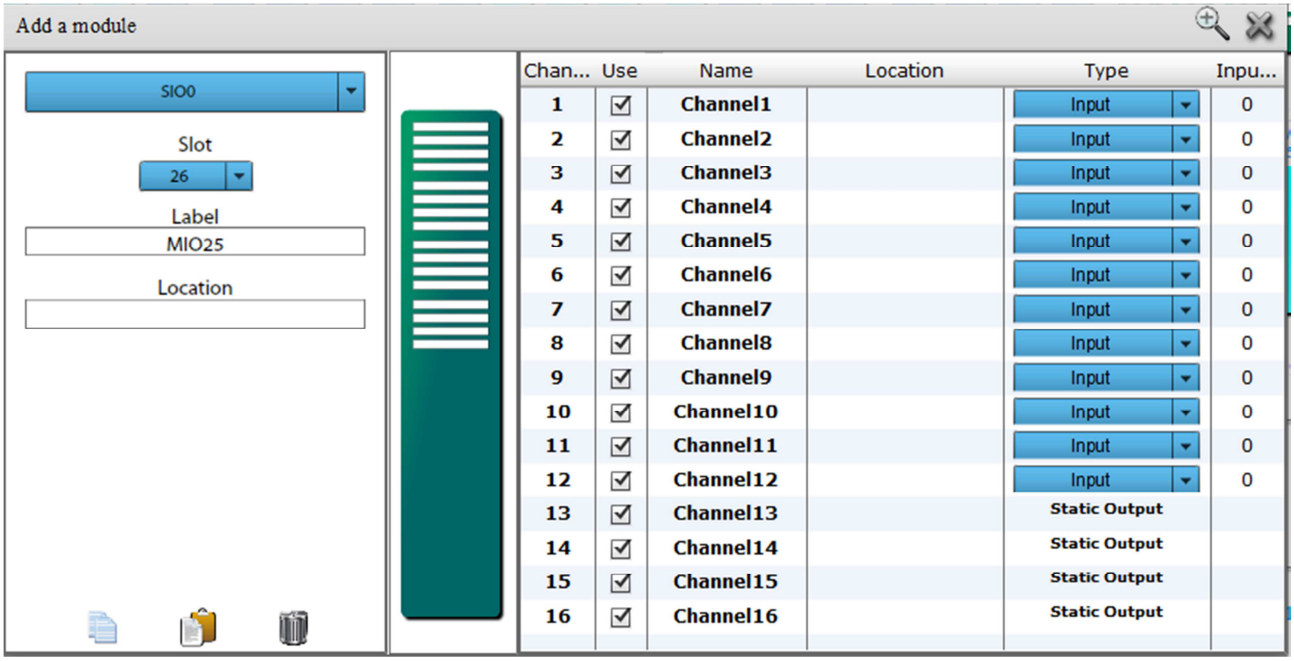
2.3.2.4 SIO0

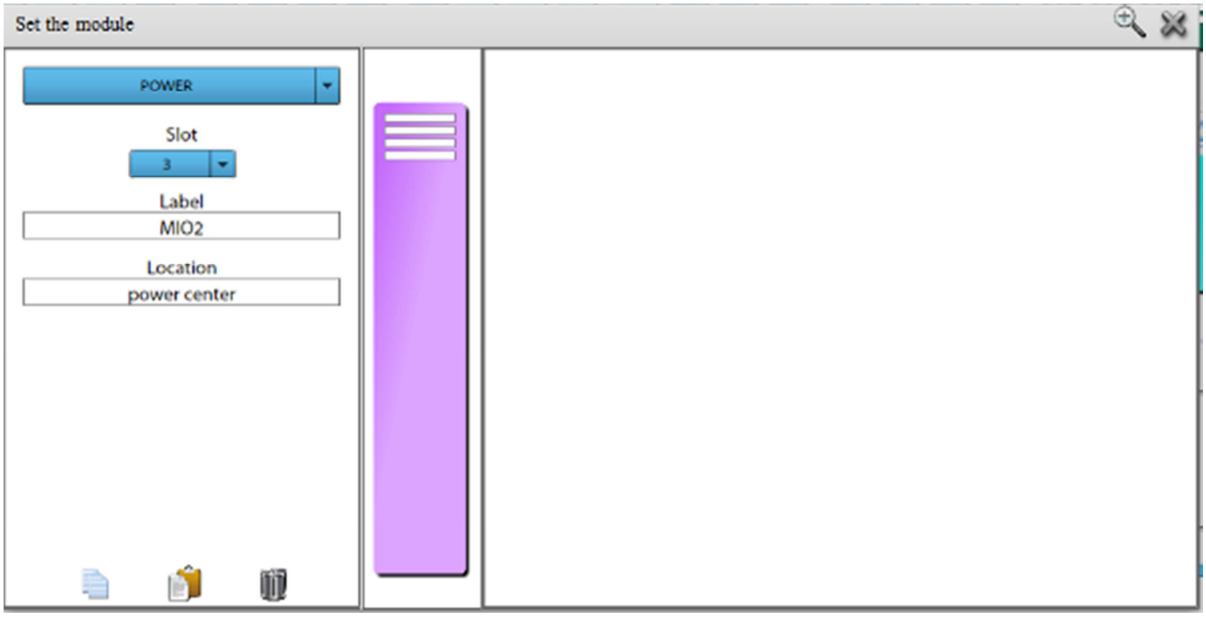
The following popup window allows configuring a SIO0 module.



The tick box column allows selecting which channel is used or not. Name and Location columns are free text fields that can be used to record additional information related to the channel.
The 12 first channels can be configured either as input or open collector output. It is performed from the drop down menu in the 'Type Column'.
When a channel is configured to be an input, it is possible to configure the current it will consume. It is done from the last column indicating a current consumption from 0 to 10mA.

2.3.2.5 Power module

The power module popup window does not propose specific configuration fields other than 'Label' and 'Location'.



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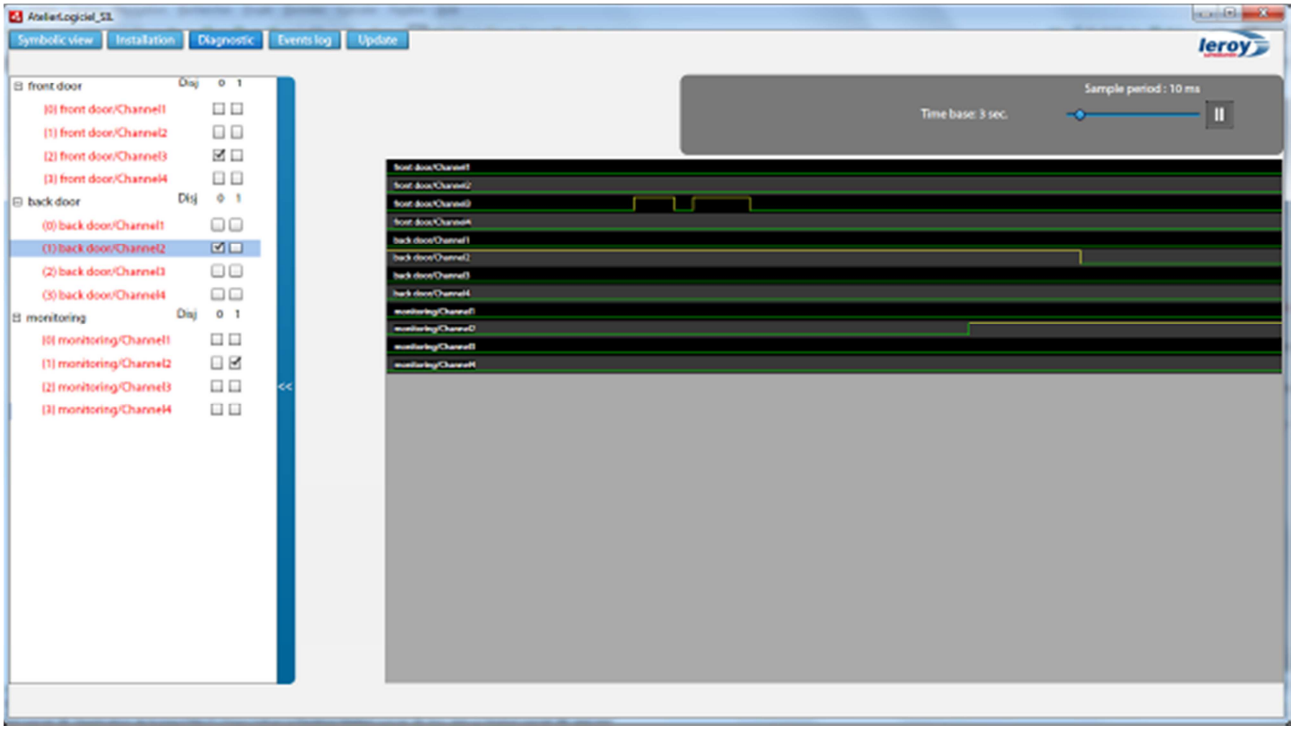
2.3.3 Boolean Equations HMI

This part will provide a simple and user-friendly graphic way to program the Boolean equation.

Under development – Planned 2015

2.3.4 Diagnostic

The diagnostic windows allows monitoring in real time any input/output managed by the system.



Just click in the left panel the signal name that you want to monitor. Its name is then displayed in red. Click again to remove it from the display zone.
The upper part of the window proposes a cursor for selecting the display full time span from 1 second to 30 seconds.
The 'pause' icon allows stopping the display scroll and then recording a screen snapshot or a data file.

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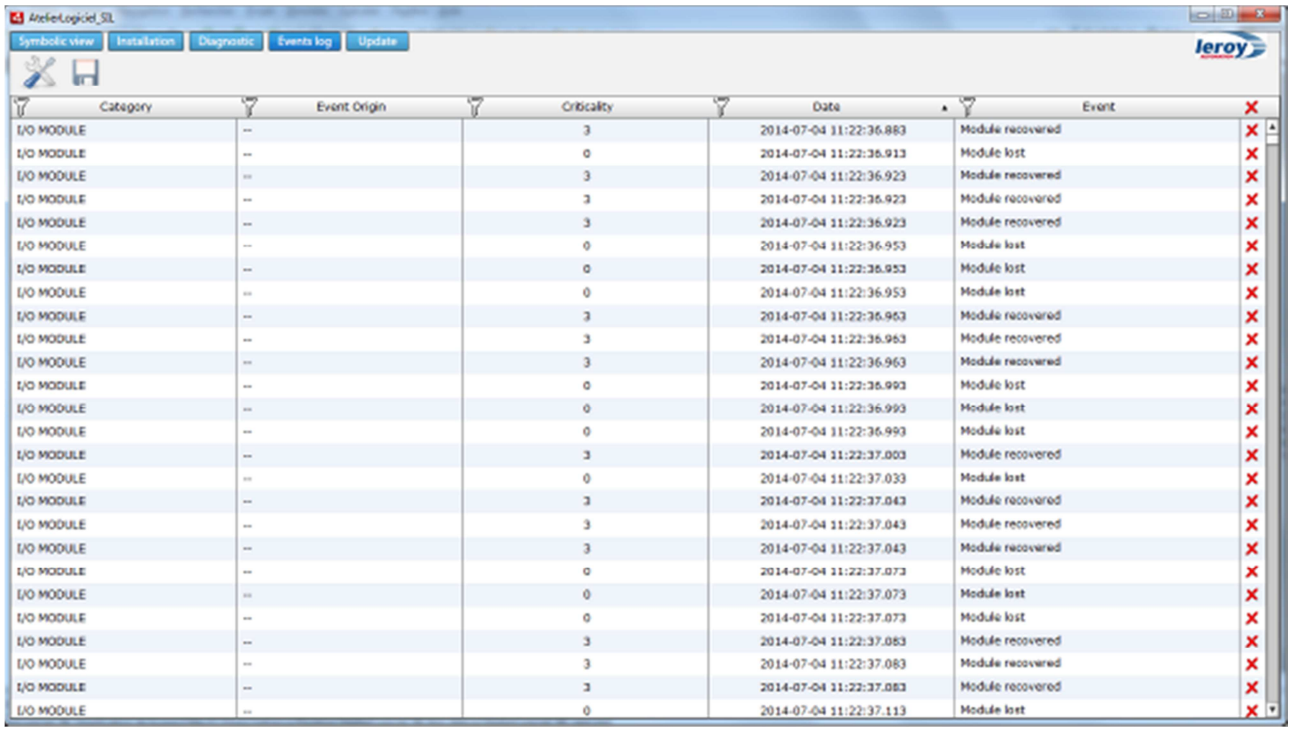
2.3.5 Events log

The events log window displays all the events recorded by the system since the last clear. The system is able to log up to 32000 events.


AtelierLogiciel_SIL
Symbolic view
Installation
Diagnostic
Events log
Update
leroy
Category
Event Origin
Criticality
Date
Event
I/O MODULE -- 3 2014-07-04 11:22:36.883 Module recovered
I/O MODULE -- 0 2014-07-04 11:22:36.913 Module lost
I/O MODULE -- 3 2014-07-04 11:22:36.923 Module recovered
I/O MODULE -- 3 2014-07-04 11:22:36.923 Module recovered
I/O MODULE -- 3 2014-07-04 11:22:36.923 Module recovered
I/O MODULE -- 0 2014-07-04 11:22:36.953 Module lost
I/O MODULE -- 0 2014-07-04 11:22:36.953 Module lost
I/O MODULE -- 0 2014-07-04 11:22:36.953 Module lost
I/O MODULE -- 3 2014-07-04 11:22:36.963 Module recovered
I/O MODULE -- 3 2014-07-04 11:22:36.963 Module recovered
I/O MODULE -- 3 2014-07-04 11:22:36.963 Module recovered
I/O MODULE -- 0 2014-07-04 11:22:36.993 Module lost
I/O MODULE -- 0 2014-07-04 11:22:36.993 Module lost
I/O MODULE -- 0 2014-07-04 11:22:36.993 Module lost
I/O MODULE -- 3 2014-07-04 11:22:37.003 Module recovered
I/O MODULE -- 0 2014-07-04 11:22:37.033 Module lost
I/O MODULE -- 3 2014-07-04 11:22:37.043 Module recovered
I/O MODULE -- 3 2014-07-04 11:22:37.043 Module recovered
I/O MODULE -- 3 2014-07-04 11:22:37.043 Module recovered
I/O MODULE -- 0 2014-07-04 11:22:37.073 Module lost
I/O MODULE -- 0 2014-07-04 11:22:37.073 Module lost
I/O MODULE -- 0 2014-07-04 11:22:37.073 Module lost
I/O MODULE -- 3 2014-07-04 11:22:37.083 Module recovered
I/O MODULE -- 3 2014-07-04 11:22:37.083 Module recovered
I/O MODULE -- 3 2014-07-04 11:22:37.083 Module recovered
I/O MODULE -- 0 2014-07-04 11:22:37.113 Module lost

Events can be displayed, filtered and sorted according to their category, origin, criticality and date. They can be individually deleted from the red cross.
The full event list can be also deleted and recorded as a csv file for further analysis.
The upper left icon displays a popup configuration windows that allows configuring for each event identified by the system its criticality, if it must be logged or not, and if it generates an alarm.

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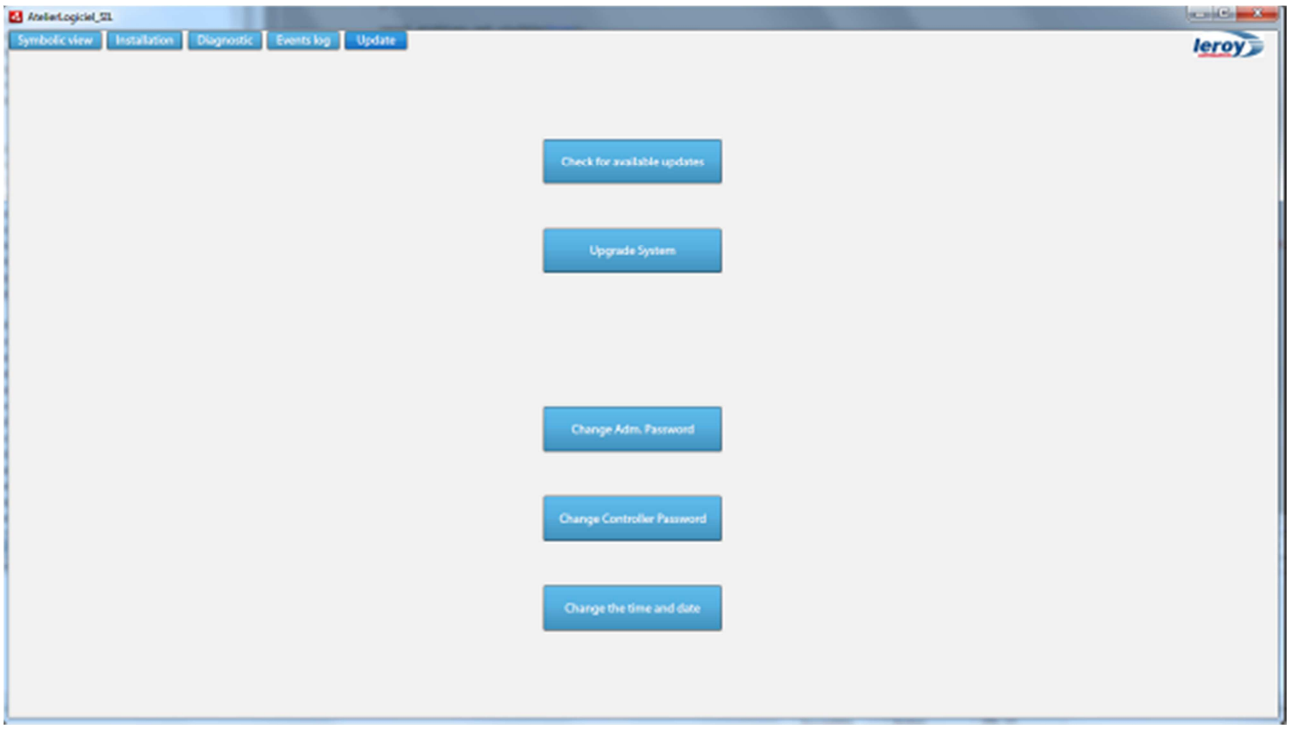
2.3.6 Update

The update window gives access to administration functions:

- ✓ Password management,
- ✓ Time and date setting,
- ✓ In the field update of the modules' firmware.

The 'Check for available updates' button requires an internet connection. It connects to Leroy Automation or Clearsy website and automatically displays firmware updates available for the modules of your system. The selected update is downloaded and recorded as a binary file on the PC.
The 'Upgrade System' button allows updating the modules' firmware from the binary file previously downloaded.



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3 The CO2 configuration workbench

This workbench allows to modify the configuration stored in the gateway (in the PIC32). This configuration can be split into 2 parts:

1) The network structure
2) The Boolean equations

These data are stored in two files:

- ".conf" file which includes safety network parameters
- ".hex" file which includes the Boolean equations.

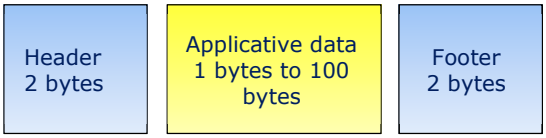
Any modification of one of these files has to be validated before starting the application in safety.

The following sub-chapter describes these parts more precisely and give information about how to modify these data.

3.1 How to connect workbench to CO2

3.1.1 Principle

The workbench and CO2 communicate with the serial interface (UART). This interface is configured at 115200 baud. When the workbench is connected to CO2 (gateway), the latter enter in a security mode and doesn't manage the Saturn network anymore. As soon as the interface is disconnected, the CO2 enters in a passing mode and it will manage the network as before.
All communication frames have the same format:



Header is: 0xFE
Footer is: 0xEF 0xDF

3.1.2 Synchronization

When a user connects the workbench to the CO2, a synchronization frame is sent to the CO2 in order to inform the latter that an external connection has occurred. This synchronization frame will be sent each second during all the connection time. The connection will be closed if this frame is not sent during 5 seconds. This behavior avoids to keep the connection opened if the user does a bad disconnection (the de-synchronization frame is sent incorrectly).

The format of the frame is described below:

Header	0x11	0x0123456789	footer

3.1.3 De-synchronization

A de-synchronization frame is sent to the CO2 when a user disconnects the workbench. The CO2 can retrieve a nominal behavior.
The format of the frame is described below:

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Header	0x22	0x9876543210	footer

3.1.4 Sending configuration data

The workbench has to be connected to the CO2 (synchronization frames are sent every seconds) to send the configuration data.

The configuration data structure is described below in §3.2 and §3.3.

The format of the frame is described below:

Header	0x55	Configuration data	footer

3.2 Network structure

These data are stored in the .conf file. The following array describes the network structure:

Nom	Description	size
i_MAC	MAC address of each module	128*8 bytes
i_IID	IID address of each module	128*8 bytes
i_Types	Module type of each module	128 bytes
i_NbIO	Number of IO of each module	128 bytes
i_VersionFirmware	Firmware version of each module	256 bytes
i_TID	TID of each module	128 bytes
i_SID	SID of each module	128*3 bytes
i_CNF_REQ	CNF_REQ of each module	128 bytes
i_CNF_CYC	CNF_CYC of each module	128 bytes
i_AD_REF	AD_REF of each module	128 bytes
i_SZ_REF	SZ_REF of each module	128 bytes
i_IO_Used	IO used of each module	128*16 bytes
i_typesIO	IO types of each module	128*2 bytes
i_SeuilDetect	Detection threshold of each module	128 bytes
i_TCYC	Network cycle time	1 byte
i_DebitReseau	Network baudrate	1 byte
i_NbAgent	Number of module in the network	1 byte

Notes:

1) Firmware version is not used so far
2) TID and SID have to verify exported constraints (please refer to §3.5)
3) CNF_REQ, CNF_CYC and TCYC cannot be set to 0.
4) IO_Used inform which IO is used on a module. This information has to be written in binary (ie : 0101000000000000 ⇔ IO2 and IO4 are used on the module)
5) Types_IO is used for SIO0 module where an IO can be configured as input or output. This information is given in binary (1010000000000000 ⇔ IO1 and IO3 are inputs others are output).
6) SeuilDetect is used only for SIO0

3.3 Boolean equations

This part describes the actual way to implement the Boolean equations. A simpler graphic way is under development (will be describe in §2.3.3). But the method described below will still be available.

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These data are stored in the .hex file.

The Boolean function is generated in a binary format (.hex) before to be send to CO2.

A .C project has to be created and compiled with the C32 compiler to generate the .hex file.
The compilation should be done in level 1 optimization (to obtain a smaller Boolean function). This optimization can be set in the pic32-gcc section of the project properties (with option categories at optimization).
A main.h file, a main.c file and a Linker_LogBool.ld file will be delivered to create this project. Only the .c file should be modified to modify the Boolean equations (comments in the .c file indicate where the Boolean equations have to be written). An example of .c file is attached below:

main.c

Note: In this file the g_TabInOut represents the state's inputs at the precedent cycle and g_TabOut represents the output (we call input all data used to commute the output (it could be physical input or output).
These two variables are arrays used by CO2 software with a size of 128*7. For each module (128 bytes) a key is associated representing the state of its IO (7 bytes).

If the module is SIL2, the key is:

SID[0]	SID[1]	SID[2]	IO1 state	IO2 state	IO3 state	IO4 state

The IO states have to be written with keys stored in the .h file. An example of .h file is attached below:

main.h

In this .h:

- ➔ IO_TRUE1 has to be used to set IO1 state to STRUE/IOTRUE
- ➔ IO_TRUE2 has to be used to set IO2 state to STRUE/IOTRUE
- ➔ IO_TRUE3 has to be used to set IO3 state to STRUE/IOTRUE
- ➔ IO_TRUE4 has to be used to set IO4 state to STRUE/IOTRUE
- ➔ IO_FALSE1 has to be used to set IO1 state to SFALSE/IOFALSE
- ➔ IO_FALSE2 has to be used to set IO2 state to SFALSE/IOFALSE
- ➔ IO_FALSE3 has to be used to set IO3 state to SFALSE/IOFALSE
- ➔ IO_FALSE4 has to be used to set IO4 state to SFALSE/IOFALSE

STRUE/SFALSE are secured Booleans used by CO2 software for outputs states of g_TabOut.
IOTRUE/IOFALSE are secured Booleans used by CO2 software for I/O states of g_TabInOut.
If the module is SIL0, the key is:

0x00	0x00	TID	IO1-8 state	IO9-16 state	N/U	N/U

The state is coded on 1 bit for each input/output.

The codding rules described in the 'main.c' file shall be respected.
Note: the 'main.h' and the linker file do not be modified. In the 'main.c' file the program must be implemented in the part tagged "/*** The following part can be modified ****/". The rest of the file must not be modified.

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Note the main.c is dedicated to an unique version of the CO2 software take to update the .C file before starting programming.

3.4 Workbench

3.4.1 Structure

The SATURN GUI software includes the following tabs:

1) Connexion :

This tab allows to user to connect from maintenance interface and to synchronize with gateway system for:

- ➔ Loading safety parameters from CO2 ToolBox tab.
- ➔ Display maintenance message

2) CO2 Toolbox :

This tab allows to user to:

- ➔ Load safety parameters (such as time cycle, baud rate, definition of the equipment on the platform,…) on gateway
- ➔ Load safety Boolean equations on gateway
- ➔ Define manually the safety parameters of the platform before sending them

3.4.2 Menu

3 menus are available:

- Actions
  - Quitter : Exit SATURNGUI software
- Manuels
  - CO2 D740 : Open the user manual
- A propos
  - About Saturn Editor : Display the version number of the software

3.4.3 Connection

This operation required to connect the gateway to a PC via a USB/RS485 convertor.
When it is done, start software.

This tab allows to activate the communication with gateway.

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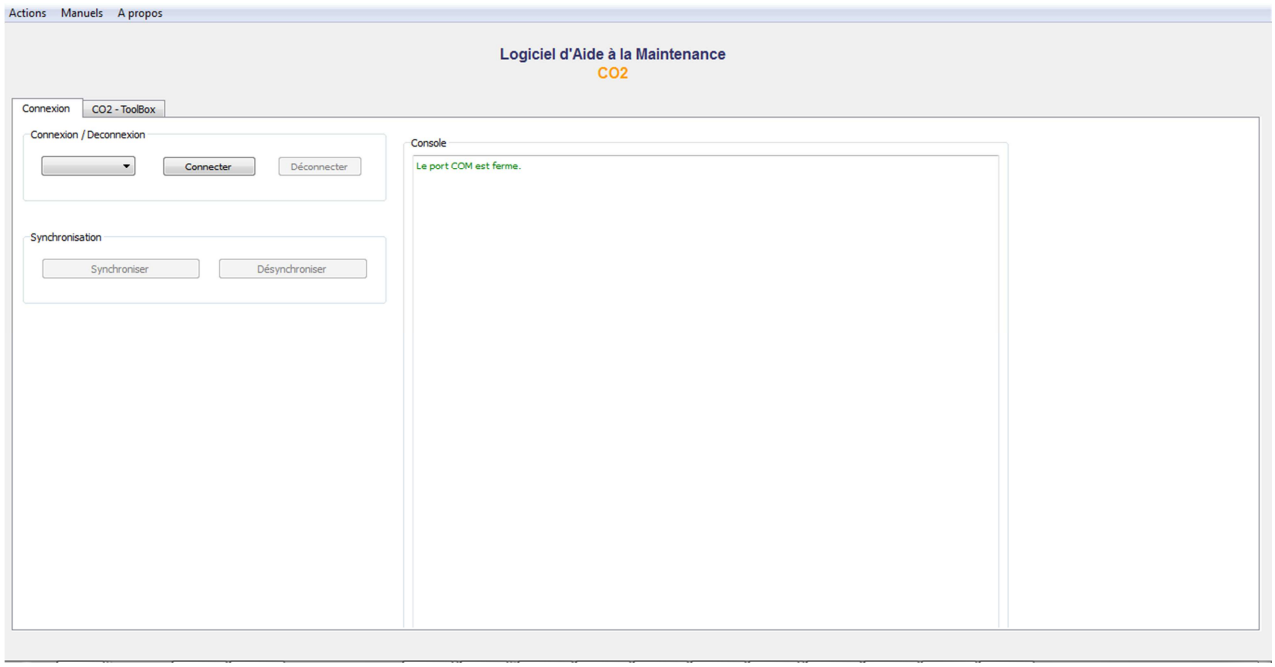
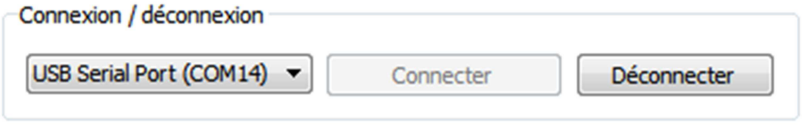


First box « connexion/déconnexion » allows to connect the PC to the system. First list box displays all available devices on the PC. When the convertor (RS485/USB) port is chosen, click on « connecter ».



A confirmation message is displayed in the console to confirm that the equipment is correctly connected. If it is not, the following message is displayed '*Impossible d'ouvrir le port (baudrate=4027528)*'.

A second box allows to synchronize or to desynchronize the PC and the CO2 (gateway):

When the system is synchronized, the equipment is blocked (nonfunctioning, waiting for configuration).

CO2 Toolbox
For description of each safety parameters please refer to 3.2.
The first tab describes safety parameters loaded on gateway or displays the structure of an unknown platform (LANSCAN of the network: it allows to see the equipment connected).
The second tab allows to send safety parameters to a CO2 (gateway) and to create ".conf" file.
On the third (and last) tab, the user can download safety parameters structure (.conf file) and Boolean equation (.hex file) already installed on gateway.

3.4.3.1 Loading data

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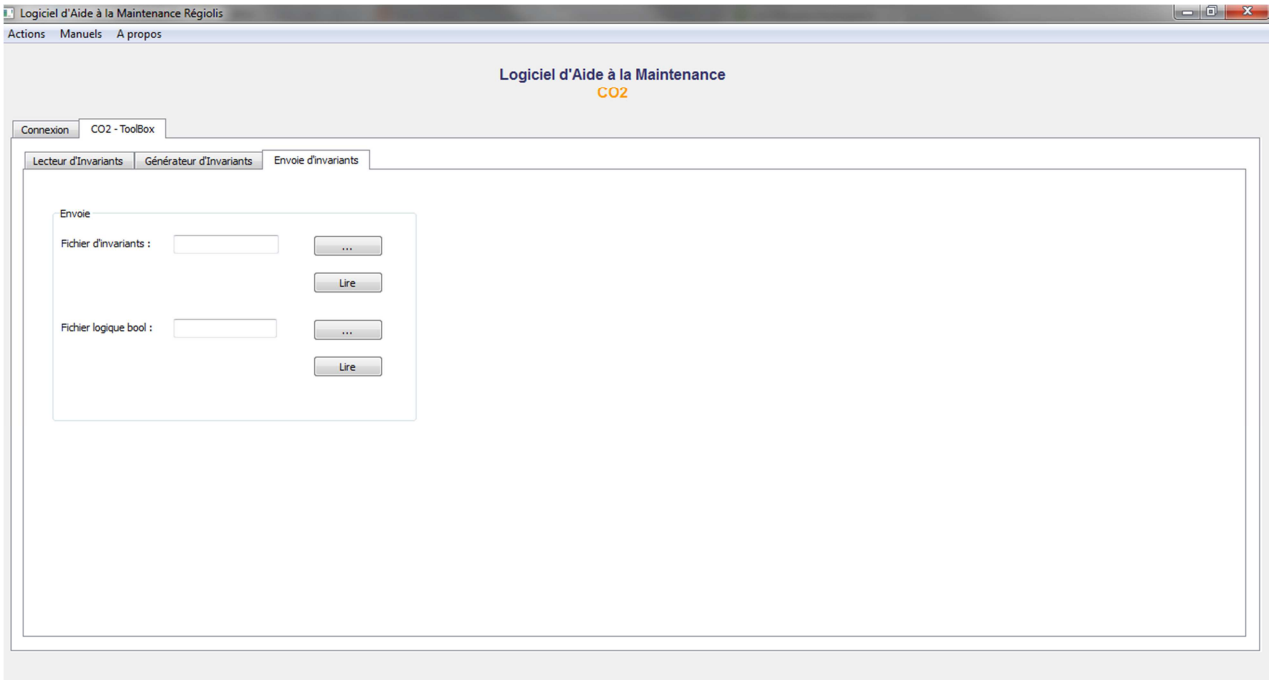
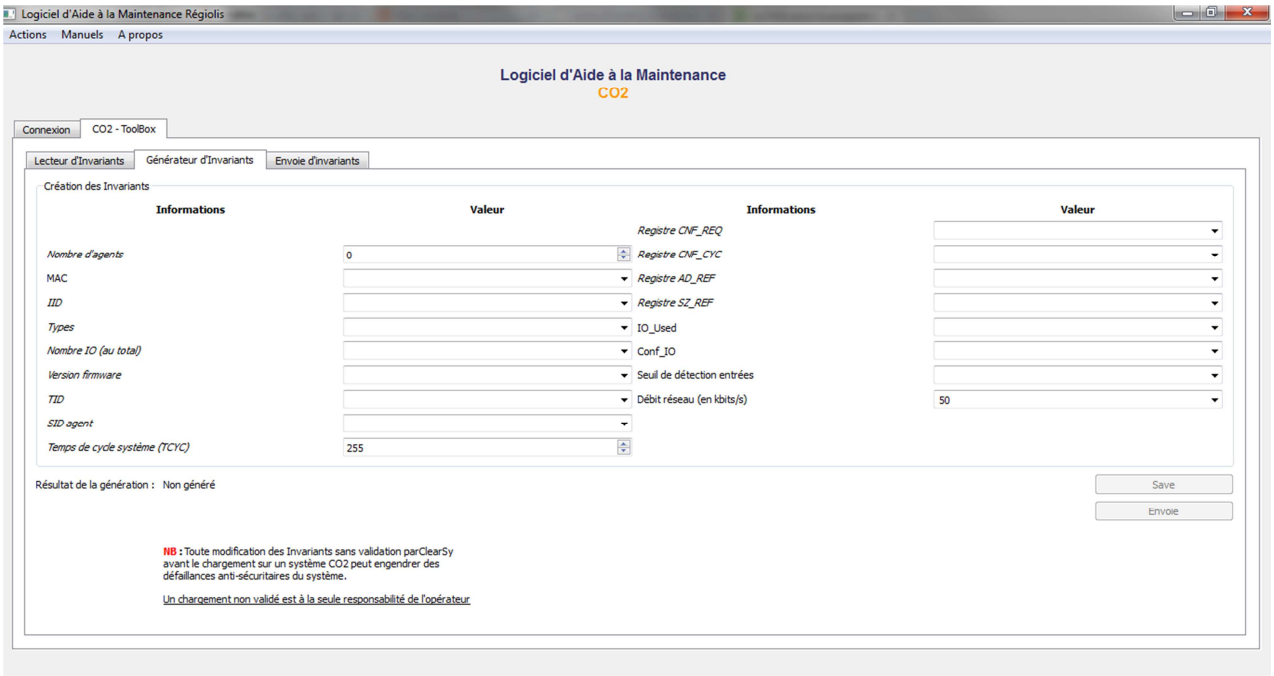


For display the safety parameters and Boolean equations (from files), the user has to find .conf file and .hex file by clicking on "Lire". After that the HMI software browses the files to display the parameters in "generateur d'invariants" tab.

3.4.3.2 Modifying and sending data



User can modify the safety parameters before sending them to the gateway.
Each parameter is linked to the number of agent on the platform. The value can be changed on drop down menu.
A primary gateway must always be positioned at index 0 of each drop module.
The values have to be given in hexadecimal byte.

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When HMI is synchronized, it is possible to send the parameter configuration and Boolean logic to gateway by clicking on the button « Envoie ».

Attention: The safety parameters will be always sent with Boolean equation. It is not possible to separate these two kinds of parameters.

3.5 Exported constraints

The following constraints are exported:

Requirement ID	Requirement	Requirement Allocation	Source document
Programming and installation requirement			
Exi_Exp_1	Gateway SID has to take the following value regarding the priority	CO2	D740-2
	è 11EE01 (primary gateway) -à priority 1		
	è 22DD02 -à priority 2		
	è 33CC03 -à priority 3		
	è 44BB04 -à priority 4		
	è 55AA05 -à priority 5		
	è 669906 -à priority 6		
	è 778807 -à priority 7		
	è 887708 -à priority 8		
Exi_Exp_2	All safety agent on network must have different SID	system	D740-2
Exi_Exp_3	Agent SID must not take the following values : 0000XXh	system	D740-2
Exi_Exp_4	All agent on network must have different TID	SO2, SI2, SIO, PWR	D740-2
Exi_Exp_5 (recommendation more than a requirement)	Agent's CNF_CYC on network must be > n+1 (n: number of redundant gateway on network)	system	D740-2
Exi_Exp_6	CNF_REQ, CNF_CYC, TCYC values cannot take 0 value	system	D740-2
Exi_Exp_7	Configuration file must be the same on each gateway on the network	CO2	D740-2
Exi_Exp_8	If no Boolean equation are needed, the user cannot put an empty file in SaturnGUI software	system	D740-2
EXPSAT_D202_SO_001	The intensity of the current command has to be limited in order to protect the system	system	D202
EXPSAT_D202_SISO_002	The system interface with SATURN agent must provide permissive command in safety way	system	D202
MAINTSAT_D202_ALL_001	People who work on the system has to be trained and carries out of electrical risk if it is necessary	system	D212

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Requirement ID	Requirement	Requirement Allocation	Source document
Programming and installation requirement			
MAINTSAT_D202_SO_002	It is recommended that preventive maintenance of the relay will be provisioned if their estimated life is < max lifetime of the system. The frequency of preventive maintenance shall be < the estimated useful life. The life time is obtained by the ratio between the maximum of switching number provided by the builder and the maximum switching number of daily cycle relay obtained according to the mission profile of the output.	system	D212
EXPSAT_D202_ALL_007	A verification process has to be set up in order to avoid every mistake risk during software loading (double validation with version verification). This requirement is also applicable on parameters	system	D212
EXPSAT_D202_ALL_008	SATURN platform configuration must take into account the intrinsic response time (IRT) oh SATURN system to be compatible with the safe response time expected by the overall system. The intrinsic response time is the sum SATURN intrinsic response times worst case of each module (TRI input modules + hub + TRI TRI output module). These times are determined by measurements taking into account the environmental conditions and the effects of any damage to components. The value obtained shall be recorded in the manual.	system	D212
ExpSAT_D212_ALL_001	Extensive tests must ensure overall good correspondence between logical treatments and outputs. It is recommended that these tests are performed at each new installation or maintenance operation requiring a logic configuration changes (equations and / or network configuration).	system	D212
ExpSAT_D212_ALL_004	Protection against DCC , the prevention of environmental risks such as temperature , humidity, EMC , vibration and shock should be ensured in accordance with the standard EN50155	system	D212
MAINTSAT_D212_ALL_001	Periodic restart SATURN system is recommended to check the operation of integrated protection on each agent.	system	
ExpSAT_D212_SI_006	The maximum voltage for restrictive input called " 0 max" that must ensure the system has to be <8 Vpp .	SI2	D212

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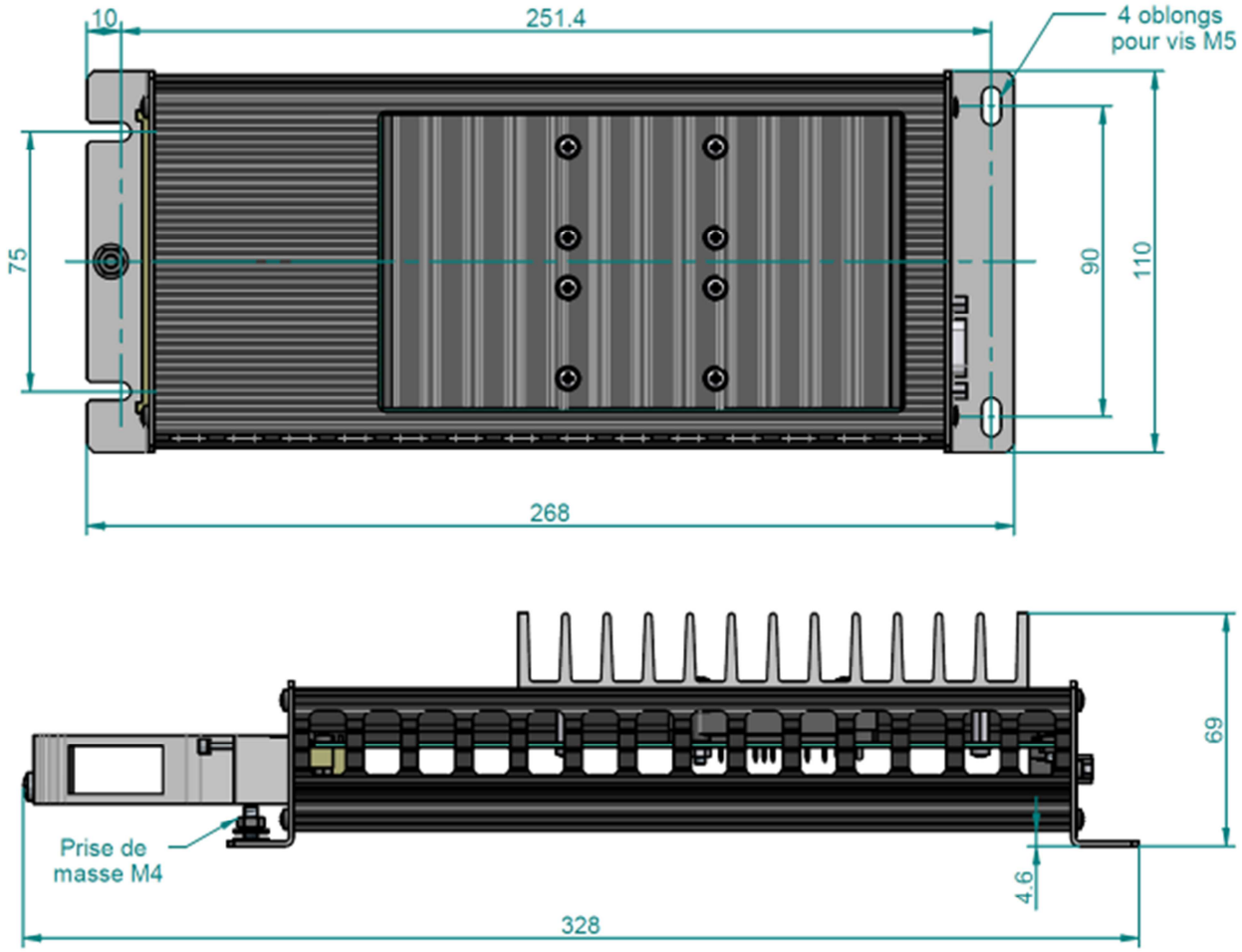
4 Mounting

4.1 Mechanical dimensions of the installed product

4.1.1 Power module – Standalone

The indicated clearance doesn't include the room necessary to mount the product nor the room necessary for tooling (screwdrivers, spanners).



4.1.2 Power module – 3U Rack

Rack version of the power module can be installed in a standard 3U x 220mm rack. Power module in rack version is 14TE width.

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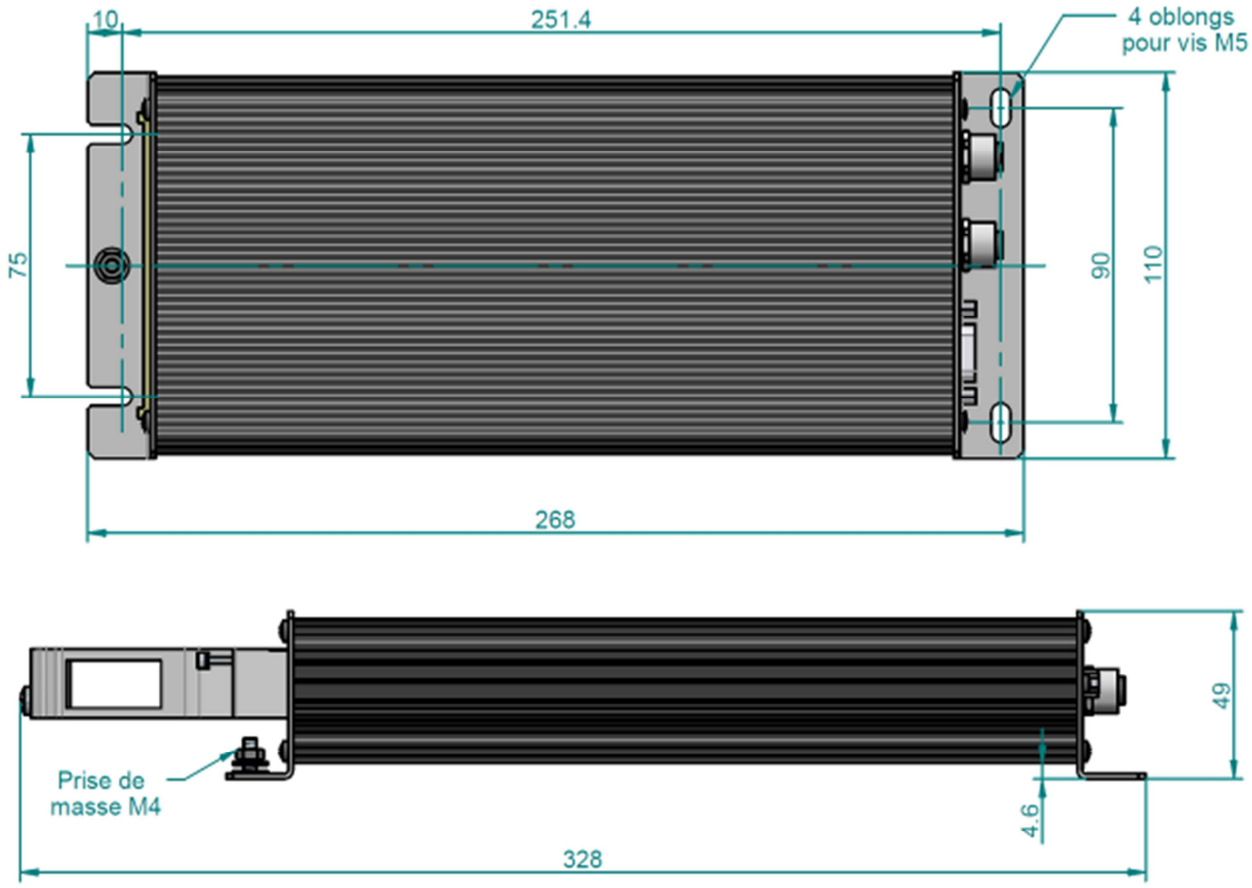
4.1.3 Other modules – Standalone

The following dimensions are applicable to all modules but power supply modules (concentrators and I/O modules).
The indicated clearance doesn't include the room necessary to mount the product nor the room necessary for tooling (screwdrivers, spanners).



4.1.4 Other modules – 3U Rack

Rack version of concentrator and I/O modules can be installed in a standard 3U x 220mm rack.
Concentrator and I/O modules in rack version are 9TE width.

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4.2 Nominal positions for standalone products

Standalone products (concentrator, I/O modules and power modules) shall be attached to a vertical wall with the 4 fastening points. Any mounting position is possible, nevertheless, it is recommended to not install the product with the F48 connector toward up position in order to avoid potential condensed water running off into the product.

The SATURN standalone modules shall be installed on an electrical conductor support (an unpainted metal panel for example) guaranteeing good chassis grounding for EMC and personnel safety purposes.
If required, specific pins of the F48 connector can be sued to ensure good product grounding.

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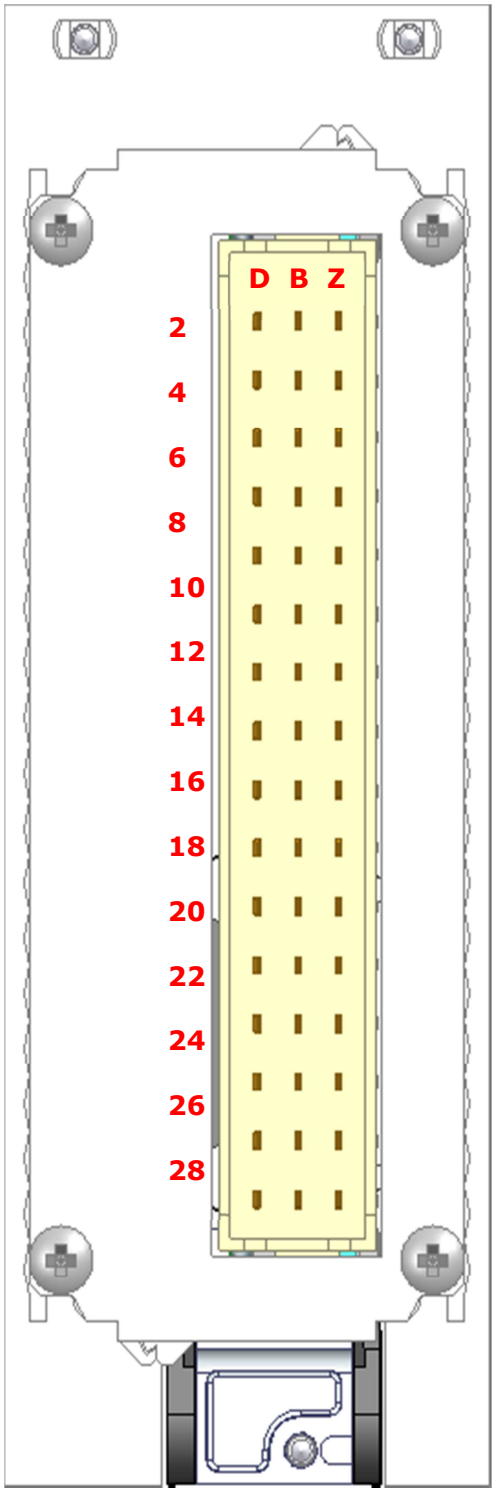
4.3 Contact layouts



Private network wiring must consist of shield twisted pair & ground reference with following characteristics:

- 100 Ohms impedance
- Max 10 Ohms / 100m
- Max 7nF / 100 m
- Max 47µH / 100 m

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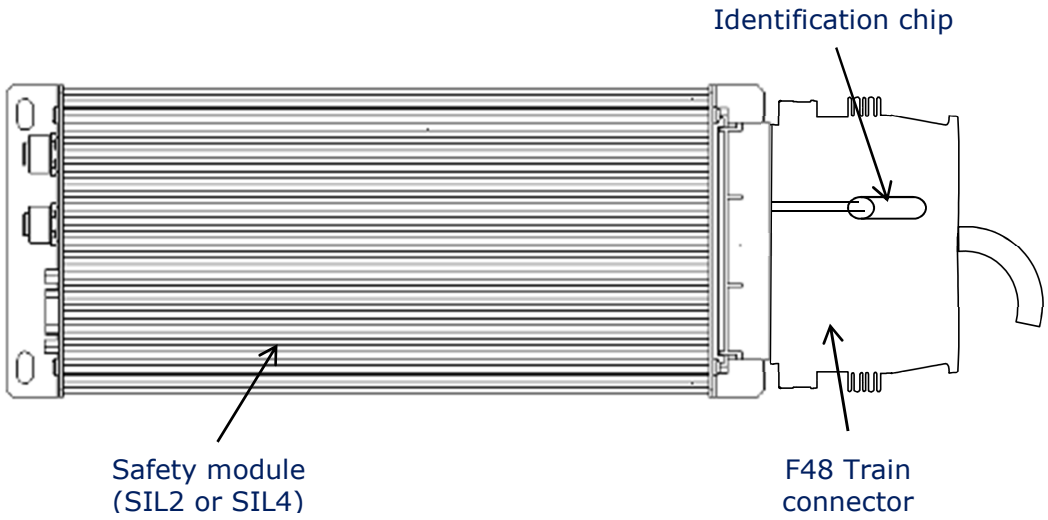
4.4 Identification chip cabling

All SATURN safety agents have to be associated with an identification chip that uniquely identifies the train connector to which the module is attached. This identification chip shall be wired in the female F48 connector as presented here after (refer to the specific section for F48 pinning definition).



Attaching the identification chip to the train connector allows quick hot-swap maintenance, avoiding any system reconfiguration.

4.5 Wiring

The communication wiring between 2 agents of the private network has to be copper shielded twisted pair with mass.
The following characteristic are recommended:

- Controlled impedance: 100 Ohm,
- 10 Ohms for 100m maximum,
- 7 nF for 100m maximum,
- 47 µH for 100m maximum

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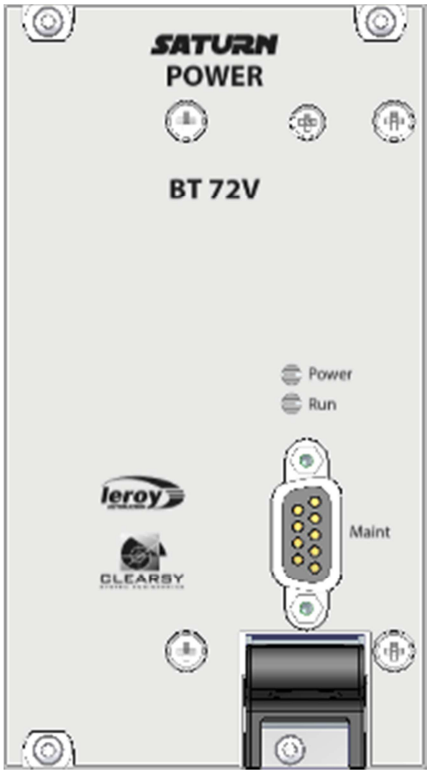
5 Power supply module

Power Supply Front face

Standalone version



Rack version

5.1 Function

Part number	Specifications
P SAT 011 001	BT 72 Power Module – Standalone mounting
P SAT 021 001	BT 72 Power Module – 3U Rack mounting

The power supply module provides the electrical power to the other modules through one ring of alternative power supply.

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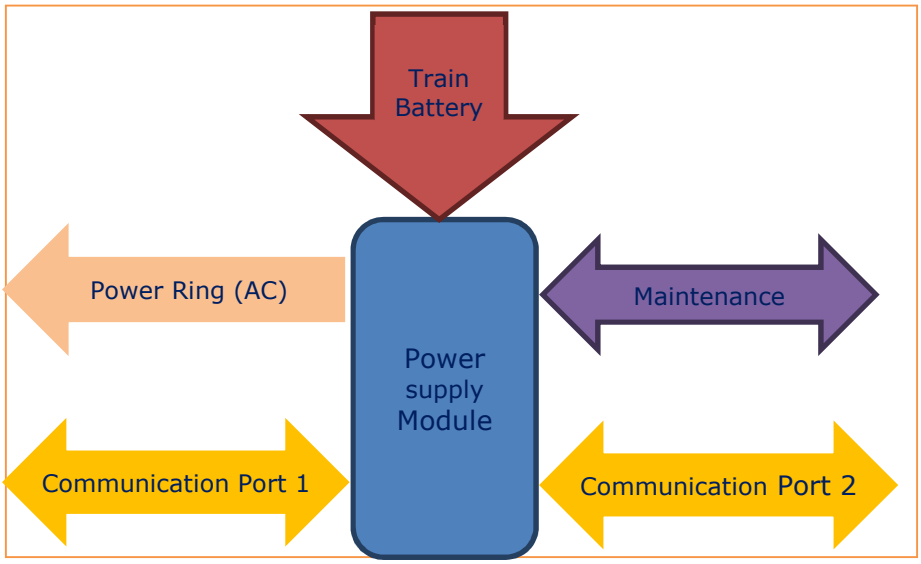

5.2 Specifications

Feature	Specifications
Power Input (BT)	72Vdc +/-40% Power supply variations according to EN50155 100Watts max Protection : Polarity reversal, undervoltage and overvoltage
Communication Port (1 and 2)	SATURN communication port
Maintenance	SATURN Maintenance port (reserved for factory operations)
Power Output	24VAC (48V peak to peak) - 100KHz – 85 Watts

5.3 F48 Pin assignment

	D	B	Z
2			
4	+BT		0BT
6			
8	+BT		0BT
10			
12	24VAC_A	24VAC_B	24VAC_B
14			
16	24VAC_A	24VAC_A	24VAC_B
18	GND	GND	GND
20			
22			
24			
26	RX2+	0LS2	TX2+
28	RX2-	0LS2	TX2-
30	RX1+	0LS1	TX1+
32	RX1-	0LS1	TX1-

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Signal name	Definition	Electrical Levels
+BT	Battery Train	+72VDC +/- 40%
0BT	Reference ground for Battery Train	-
24VAC_A 24VAC_B	Delivered power supply for SATURN modules	24VAC (48V pk to pk) 100KHz
GND	Chassis case reference ground	-
RX1+ / RX1- TX1+ / TX1-	Communication network port 1	RS485
0LS1	Reference ground for communication port 1	-
RX2+ / RX2- TX2+ / TX2-	Communication network port 2	RS485
0LS2	Reference ground for communication port 2	-

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5.4 Diagnostic and Maintenance

5.4.1 Maintenance port

See section1.6.

5.4.2 Set of Led

Led	State	Information
Power	Off	Module powered off
	Red fix	Module powered on - FPGA not configured
	Green fix	Module powered on – FPGA operational
Run	Off	Module powered off
	Red fix	Module not synchronized by the communication network
	Green blink	Module synchronized by the communication network

5.5 Delivered power supply

The power supply is not mandatory for a well-functioning SATURN platform. User can use another equipment to supply SATURN agent, however the power supply of each SATURN module has to be compliant with the following specification:

- 24Vac 100KHz +/- 10KHz,
- Power computed regarding the number of SATURN module

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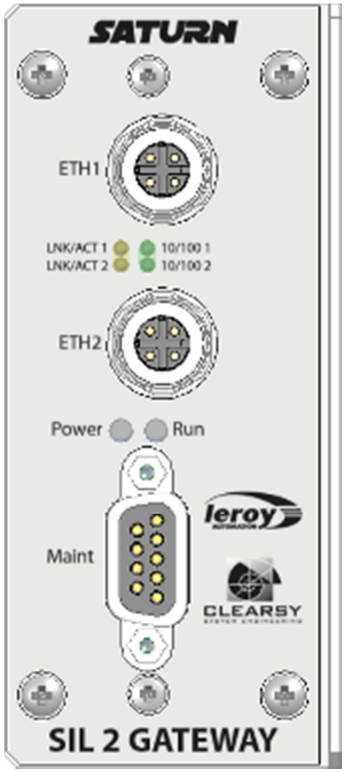
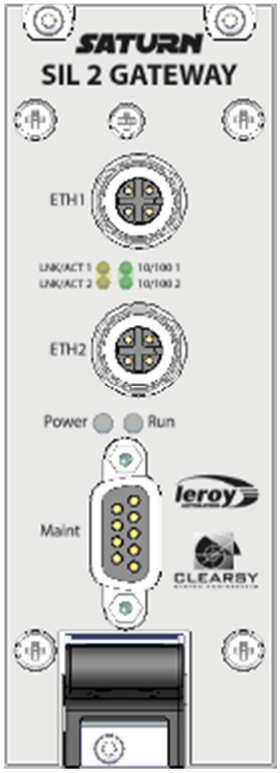
6 Gateway

Concentrator Front face



Standalone version



Rack version

6.1 Function

Part number	Specifications
P SAT 212 010	Concentrator with EIP Protocol – SIL 2 – Standalone mounting
P SAT 222 010	Concentrator with EIP Protocol – SIL 2 – 3U Rack mounting

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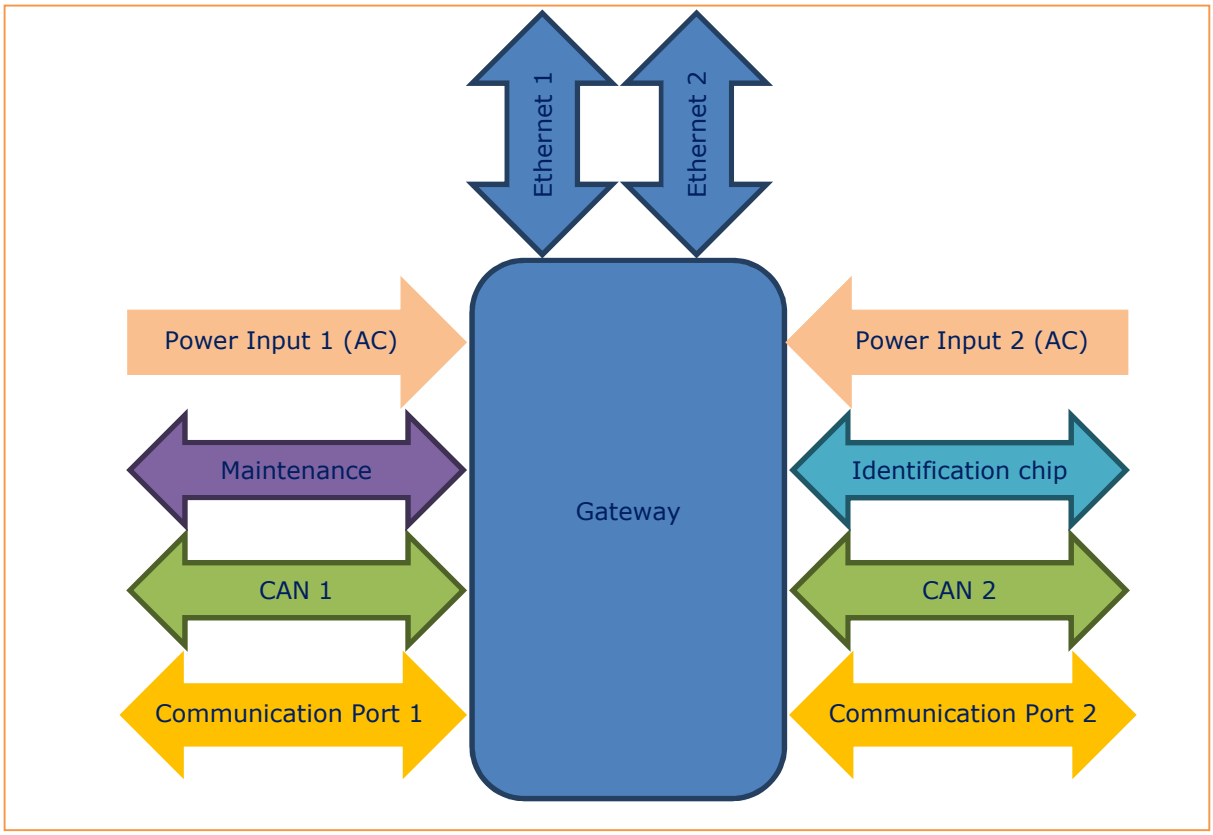

6.2 Specifications

Feature	Specifications
Power Input (1 or 2)	24VAC +/- 3V 100KHz 6Watts max
Ethernet (1 or 2)	Compliant 802.3 Protocol EIP (can be customized from customer's specification) Port 1 and port 2 are equivalent and daisy chained (internal switch) Ethernet daisy chain is maintained even if gateway is not powered
Identification chip	Identification chip 1 wire protocol 64 bits code
Communication Port (1 and 2)	SATURN communication port
Maintenance	SATURN Maintenance port (reserved for factory operations)
CAN (1 and 2)	Compliant Bosch CAN 2.0B CANo protocol (provision)

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6.3 F48 Pin assignment

	D	B	Z
2		CAN1_L	
4		CAN1_H	
6		CAN2_L	
8		CAN2_H	
10		CAN_0V	
12	MAINT2RX+		MAINT2TX+
14		MAINT2_0V	
16	MAINT2RX-		MAINT2TX-
18	GND	GND	GND
20	IC_DATA	IC_0V	IC_0V
22	24VAC_1A	24VAC_1B	24VAC_1B
24	24VAC_2A	24VAC_2B	24VAC_2B
26	RX2+	0LS2	TX2+
28	RX2-	0LS2	TX2-
30	RX1+	0LS1	TX1+
32	RX1-	0LS1	TX1-

Signal name	Definition	Electrical Levels
CAN1_L / CAN1_H	CAN interface 1	Bosch 2.0B
CAN2_L / CAN2_H	CAN interface 2	Bosch 2.0B
CAN_0V	Reference ground for CAN interfaces	-
MAINT2RX+ / MAINT2RX- MAINT2TX+ / MAINT2TX-	Maintenance port 2 (not used)	RS485
MAINT2_0V	Reference ground for maintenance port 2	-
GND	Chassis case reference ground	-
IC_DATA	Identification Chip (Data + Power)	One Wire
IC_0V	Reference ground for identification chip	-
24VAC2_A 24VAC2_B	Power supply port 2	24VAC +/- 3V 100KHz
24VAC1_A 24VAC1_B	Power supply port 1	24VAC +/- 3V 100KHz
RX1+ / RX1- TX1+ / TX1-	Communication network port 1	RS485
0LS1	Reference ground for communication port 1	-
RX2+ / RX2- TX2+ / TX2-	Communication network port 2	RS485
0LS2	Reference ground for communication port 2	-

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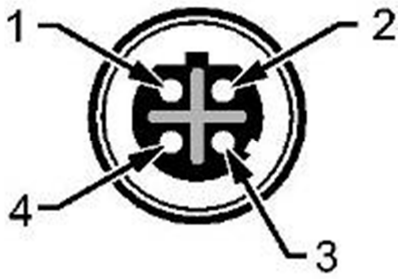
6.4 M12 Pin assignment

The gateway front face is equipped with 2 M12 connectors for Ethernet communication.



Pin	Designation	Comment
1	TD+	Transmission Data +
2	RD+	Reception Data +
3	TD-	Transmission Data -
4	RD-	Reception Data -

6.5 Diagnostic and Maintenance

6.5.1 Maintenance port

See section1.6.

6.5.2 Set of Led

Led	State	Information
Power	Off	Module powered off
	Red fix	Module powered on - FPGA not configured
	Green fix	Module powered on – FPGA operational
Run	Off	Module powered off
	Red fix	Software not operational or communication cycle not yet started
	Green blink	Software operational and communication cycle started

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7 SO2 – 4 SIL2 Outputs

SO2 Front face

Standalone version

Rack version

7.1 Function

Part number	Specifications
P SAT 213 001	4 digital outputs – SIL 2 - Standalone mounting
P SAT 223 001	4 digital outputs – SIL 2 – 3U Rack mounting

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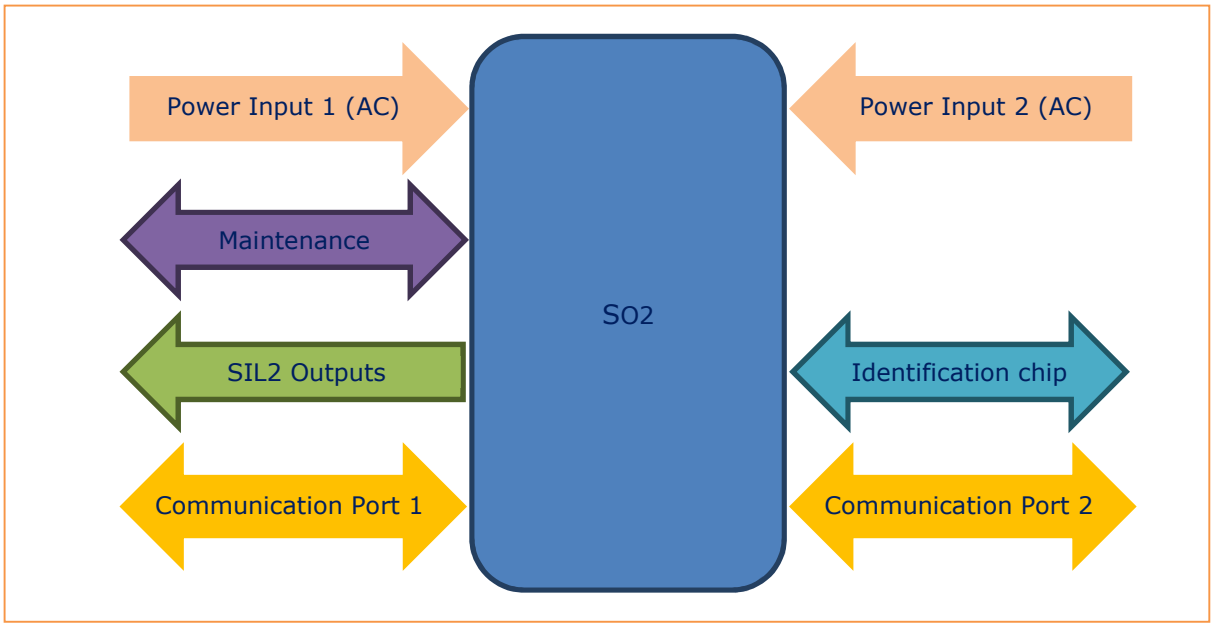

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7.2 Specifications

Feature	Specifications
Power Input (1 or 2)	24VAC +/- 3V 100KHz 12Watts max
Identification chip	Identification chip 1 wire protocol 64 bits code
Communication Port (1 and 2)	SATURN communication port
Maintenance	SATURN Maintenance port (reserved for factory operations)
SIL2 Outputs	4 Relay Outputs with 1 make contact (NO) See characteristics below

7.2.1 Relay outputs characteristics

The 4 SIL 2 relay outputs have the same following characteristics:

Feature	Value
Contact material	AgNi + 5µm Au
Rated insulation voltage	250 VAC
Min. Switching voltage[2]	10 VDC / 10 VAC 100 mVDC / 100mVAC[1]
Max. Switching voltage[2]	250 VDC / 400 VAC 60 VDC / 60 VAC[1]
Min. Switching current[2]	10 mA 1 mA[3]
Max. Switching current[2]	3 A DC / 2 A AC 0.3 A[3]
Min. Switching power[2]	3 VA / 3 W 1mVA / 1 mW[4]
Max. Switching power[2]	200 VA / 200 W 7 VA / 7 W[4]
Electrical life (see Figure 2 for complete figure)	> 2.2e[5] cycles with 230VAC, 3A, cos φ = 1
Max. Activation time	15 ms
Max. Release time	12 ms
Output to output insulation	2000 Vrms

[1] If the operating voltage is greater than 60VDC, the 5µm gold layer will be degraded and the minimum voltage will be 10V instead of 100mV.
[2] Refer to Figure 1 for the maximum recommended voltage/current ratio.
[3] If the operating current is greater than 0.3 A, the 5µm gold layer will be degraded and the minimum current will be 10mA instead of 1mA.
[4] If the operating power is greater than 7W, the 5µm gold layer will be degraded and the minimum power will be 100mW instead of 1mW.

Table 1 – SIL 2 Relay outputs characteristics

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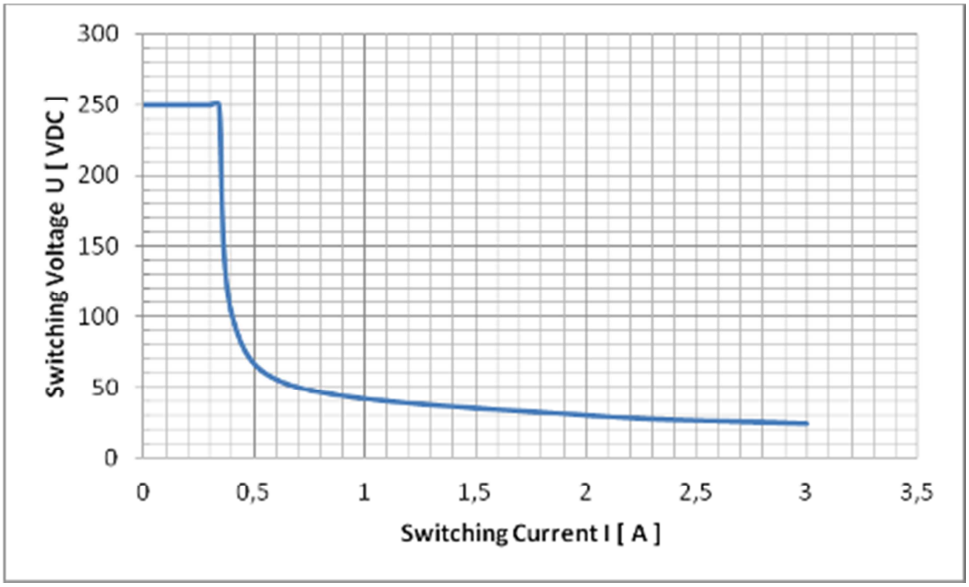

Figure 1 - Limit curve fro arc-free operation

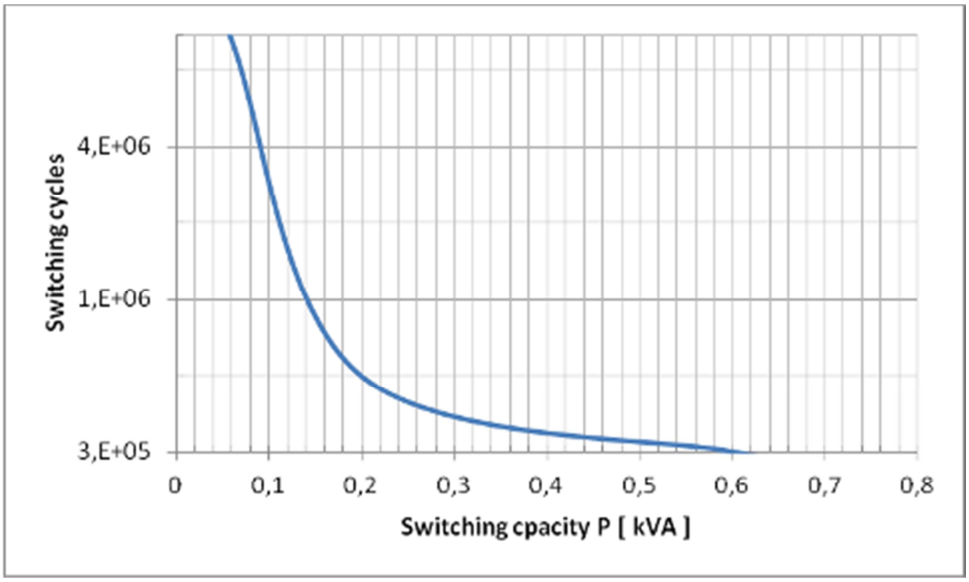

Figure 2 – Contact service life

7.2.2 Relay outputs protection

The 4 relay outputs are not protected against overvoltage or overcurrent. It is user's responsibility to ensure that relay outputs are never used above maximum conditions defined in Table 1.
Namely, a circuit breaker shall be installed on the loop to ensure that maximum allowable current is never exceeded.

7.2.3 Conditions of operation

The safety integrity level 2 for the related fear event (a relay is never closed while expecting not) is guaranteed provided that the following conditions are always met:

- ✓ Maximum rating given in Table 1, Figure 1 and Figure 2 are always met

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- ✓ A circuit breaker is installed on the output loop
- ✓ The output command received from the communication network shall be provided with a SIL in relation with the function (SIL 2 or higher)
- ✓ Environmental requirements given in §10 are met

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7.3 F48 Pin assignment

	D	B	Z
2	R1W	NC	NC
4	NC	NC	R1C
6	R2W	NC	NC
8	NC	NC	R2C
10	R3W	NC	NC
12	NC	NC	R3C
14	R4W	NC	NC
16	NC	NC	R4C
18	GND	GND	GND
20	IC_DATA	IC_0V	IC_0V
22	24VAC_1A	24VAC_1B	24VAC_1B
24	24VAC_2A	24VAC_2B	24VAC_2B
26	RX2+	0LS2	TX2+
28	RX2-	0LS2	TX2-
30	RX1+	0LS1	TX1+
32	RX1-	0LS1	TX1-

Signal name	Definition	Electrical Levels
R1W / R1C R2W / R2C R3W / R3C R4W / R4C	Relay contacts for the 4 SIL 2 outputs	See §7.2
GND	Chassis case reference ground	-
IC_DATA	Identification Chip (Data + Power)	One Wire
IC_0V	Reference ground for identification chip	-
24VAC2_A 24VAC2_B	Power supply port 2	24VAC +/- 3V 100KHz
24VAC1_A 24VAC1_B	Power supply port 1	24VAC +/- 3V 100KHz
RX1+ / RX1- TX1+ / TX1-	Communication network port 1	RS485
0LS1	Reference ground for communication port 1	-
RX2+ / RX2- TX2+ / TX2-	Communication network port 2	RS485
0LS2	Reference ground for communication port 2	-

Note: Pins NC are "no connect" on the SO2 board but shall be used for safety output pins passivation. They shall be connected in the F48 counterpart connector to the appropriate reference voltage in such a way that a potential F48 pin bending, and the resulting short circuit, will not lead to an unsafe situation.

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7.4 Diagnostic and Maintenance

7.4.1 Maintenance port

See section1.6.

7.4.2 Set of Led

Led	State	Information
Power	Off	Module powered off
	Red fix	Module powered on - FPGA not configured
	Green fix	Module powered on – FPGA operational
Run	Off	Module powered off
	Red fix	Module in fallback mode
	Green blink	Module in normal mode

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8 SI2 – 4 SIL2 Inputs

SI2 Front face

Standalone version

Rack version

8.1 Function

Part number	Specifications
P SAT 213 002	4 digital inputs – SIL 2 - Standalone mounting
P SAT 223 002	4 digital inputs – SIL 2 – 3U Rack mounting

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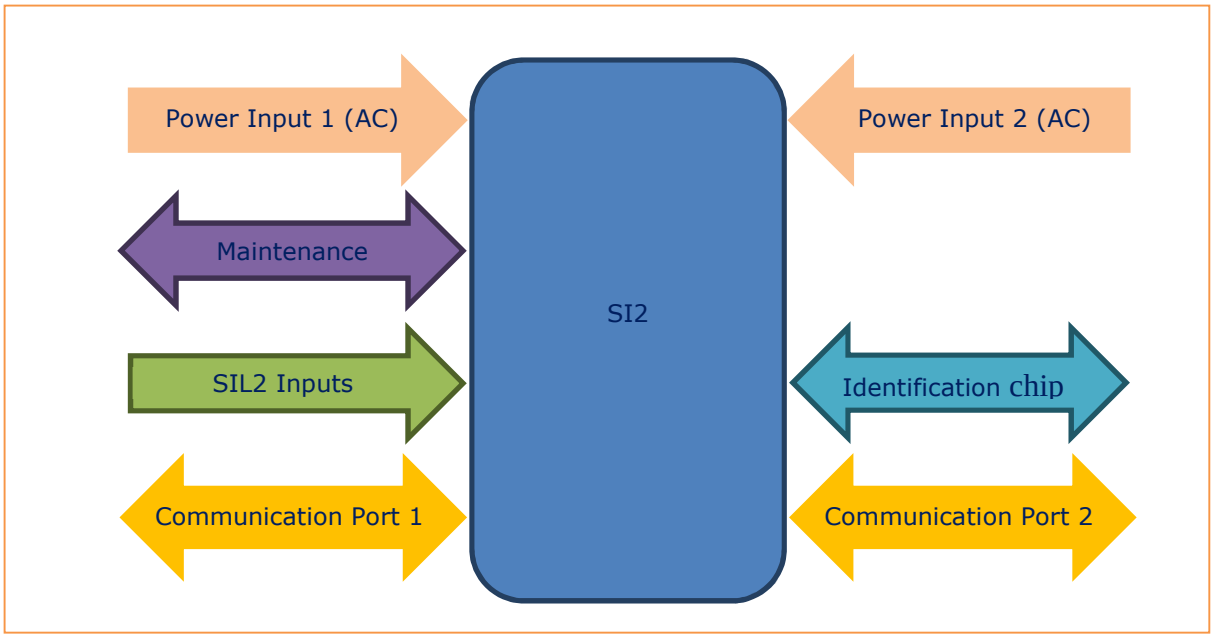

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8.2 Specifications

Feature	Specifications
Power Input (1 or 2)	24VAC +/- 3V 100KHz 12Watts max
Identification chip	Identification chip 1 wire protocol 64 bits code
Communication Port (1 and 2)	SATURN communication port
Maintenance	SATURN Maintenance port (reserved for factory operations)
SIL2 Inputs	4 SIL 2 Inputs See characteristics below

8.2.1 SIL 2 Inputs characteristics

The 4 SIL 2 inputs have the same following characteristics:

Feature	Value
Nominal voltage (Un)	72VDC
Maximal voltage	1.4xUn = 101 VDC
Input current	10mA (typical for Un = 72VDC)
Guaranteed levels	< 8 VDC → Logical '0' > 40 VDC → Logical '1'
Logical '1' max. detection time	10 ms
Logical '0' max. detection time	10 ms
Input to input insulation	2000 Vrms

Table 2 – SIL 2 Inputs characteristics

8.2.2 Inputs protection

The 4 inputs are protected against overvoltage with a bidirectional 170V transil. Maximal peak pulse power that can be dissipated by the transil is given by the figure below:

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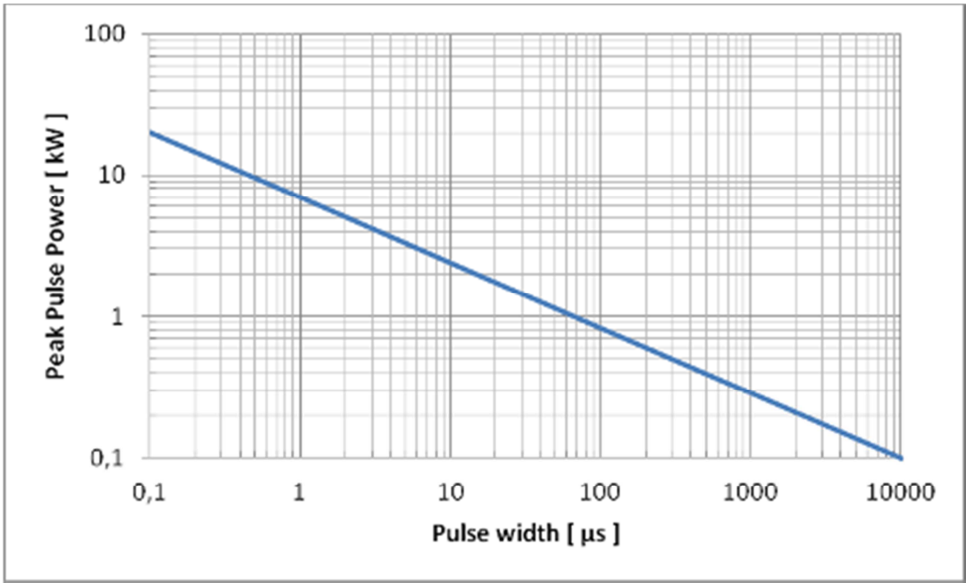

Figure 3 – Peak pulse power rating curve

8.2.3 Conditions of operation

The safety integrity level 2 for the related fear event (a logical '1' is seen on an input while it is actually not) is guaranteed provided that the following conditions are always met:

- ✓ Maximum rating given in Table 2 and Figure 3 are always met
- ✓ Environmental requirements given in §10 are met

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8.3 F48 Pin assignment

	D	B	Z
2	I1	NC	I1_0V
4	NC	NC	NC
6	I2	NC	I2_0V
8	NC	NC	NC
10	I3	NC	I3_0V
12	NC	NC	NC
14	I4	NC	I4_0V
16	NC	NC	NC
18	GND	GND	GND
20	IC_DATA	IC_0V	IC_0V
22	24VAC_1A	24VAC_1B	24VAC_1B
24	24VAC_2A	24VAC_2B	24VAC_2B
26	RX2+	0LS2	TX2+
28	RX2-	0LS2	TX2-
30	RX1+	0LS1	TX1+
32	RX1-	0LS1	TX1-

Signal name	Definition	Electrical Levels
I1 / I1_0V I2 / I2_0V I3 / I3_0V I4 / I4_0V	Input signal and related reference ground for the 4 SIL 2 inputs	See §8.2
GND	Chassis case reference ground	-
IC_DATA	Identification Chip (Data + Power)	One Wire
IC_0V	Reference ground for identification chip	-
24VAC2_A 24VAC2_B	Power supply port 2	24VAC +/- 3V 100KHz
24VAC1_A 24VAC1_B	Power supply port 1	24VAC +/- 3V 100KHz
RX1+ / RX1- TX1+ / TX1-	Communication network port 1	RS485
0LS1	Reference ground for communication port 1	-
RX2+ / RX2- TX2+ / TX2-	Communication network port 2	RS485
0LS2	Reference ground for communication port 2	-

Note: Pins NC are "no connect" on the SI2 board but shall be used for safety input pins passivation. They shall be connected in the F48 counterpart connector to the appropriate reference voltage in such a way that a potential F48 pin bending, and the resulting short circuit, will not lead to an unsafe situation.

8.4 Diagnostic and Maintenance

8.4.1 Maintenance port

See section1.6.

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8.4.2 Set of Led

Led	State	Information
Power	Off	Module powered off
	Red fix	Module powered on - FPGA not configured
	Green fix	Module powered on – FPGA operational
Run	Off	Module powered off
	Red fix	Module in fallback mode
	Green blink	Module in normal mode

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9 SIO0 – 12 SIL0 I/O + 4 SIL0 Outputs

SIO0 Front face

Standalone version

Rack version

9.1 Function

Part number	Specifications
P SAT 013 001	12 digital inputs/outputs+4 outputs – SIL 0 - Standalone mounting
P SAT 023 001	12 digital inputs/outputs+4 outputs – SIL 0 - 3U Rack mounting

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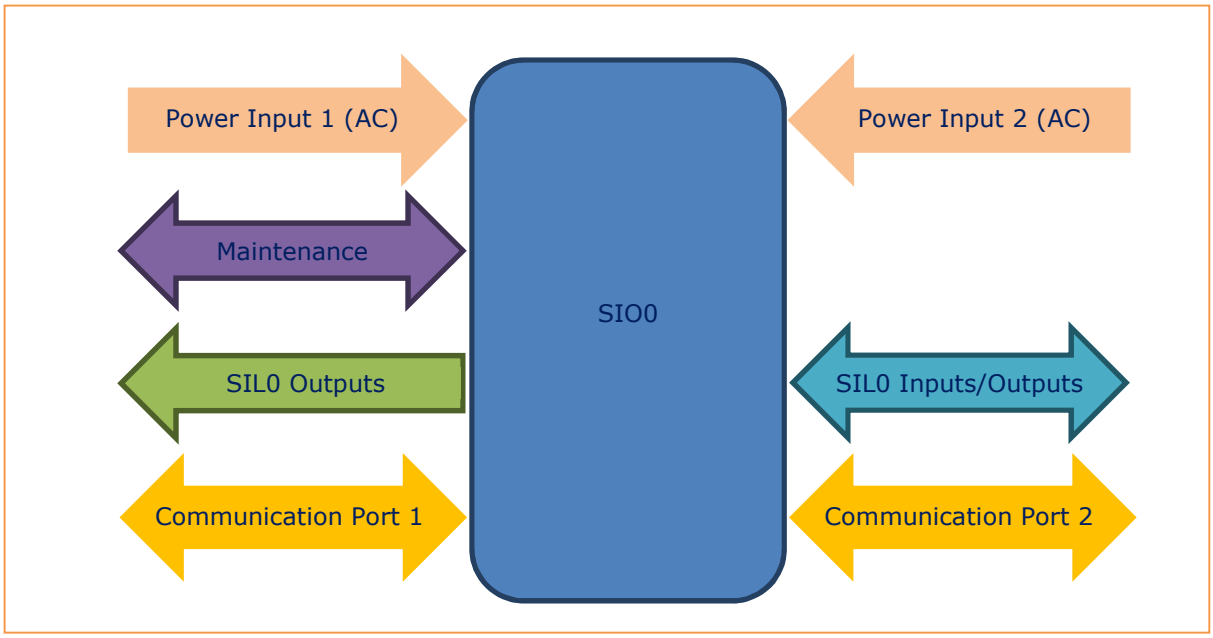

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9.2 Specifications

Feature	Specifications
Power Input (1 or 2)	24VAC +/- 3V 100KHz 4 Watts max
Communication Port (1 and 2)	SATURN communication port
Maintenance	SATURN Maintenance port (reserved for factory operations)
SIL0 Outputs	4 isolated polarized Solid State Relay outputs See characteristics below
SIL0 Inputs/Outputs	12 non isolated configurable line (input or open collector output) See characteristics below

9.2.1 SIL 0 outputs characteristics

The 4 SIL 0 Solid State Relay (SSR) outputs have the same following characteristics:

Feature	Value
Nominal Switching voltage	24VDC to 110VDC
Max. Switching voltage	154 VDC
Max. $R_{DS(on)}$	60 mΩ
Nominal Switching current	3 A
Max. Switching current	10 A (100ms)
Max. Activation time	<300 µs
Max. Release time	<500 µs
Output to output insulation	1500 Vrms

Table 3 – SIL 0 Solid State Relay outputs characteristics

9.2.2 Solid State Relay outputs protection

The 4 SSR outputs are protected against:

- ✓ Overvoltage
- ✓ Polarity inversion

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9.2.3 SIL 0 Inputs/Outputs characteristics

The 12 SIL 0 line configurable as inputs or outputs have the same following characteristics:

Feature	Value
Line to line insulation	No
Configured as input	
Input Type	P Type
Input Nominal voltage (Un)	72VDC
Input Max. voltage	1.4xUn = 101 VDC
Input current	0 to 10mA Each line individually tuned by configuration (see §2.2)
Guaranteed logical levels	Tuned by configuration (see §2.2)
Response time	1 ms (low pass filter)
Line to line insulation	No
Configured as output	
Output Type	Open Collector
Nominal Switching voltage	24VDC to 110VDC
Max. Switching voltage	154 VDC
Max. $R_{DS(on)}$	60 mΩ
Nominal Switching current	3 A
Max. Switching current	10 A (100ms)
Max. Activation time	<300 µs
Max. Release time	<500 µs

Table 4 – SIL 0 Inputs/Outputs characteristics

9.2.4 Inputs/Outputs protection

The 12 inputs/outputs are protected against:

- ✓ Overvoltage
- ✓ Polarity inversion

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9.3 F48 Pin assignment

	D	B	Z
2	IO1	IO2	IO3
4	IO4	IO5	IO6
6	IO7	IO8	IO9
8	IO10	IO11	IO12
10	ST1+		ST1-
12	ST2+		ST2-
14	ST3+		ST3-
16	ST4+		ST4-
18	GND	GND	GND
20	0VES	0VES	0VES
22	24VAC_1A	24VAC_1B	24VAC_1B
24	24VAC_2A	24VAC_2B	24VAC_2B
26	RX2+	0LS2	TX2+
28	RX2-	0LS2	TX2-
30	RX1+	0LS1	TX1+
32	RX1-	0LS1	TX1-

Signal name	Definition	Electrical Levels
IO1, IO2, IO3, IO4, IO5, IO6, IO7, IO8, IO9, IO10, IO11, IO12	Configurable inputs/open collector outputs	See §9.2
0VES	Reference ground for I/O signals	-
ST1+ / ST1- ST2+ / ST2- ST3+ / ST3- ST4+ / ST4-	Isolated polarized Solid State Relay outputs	See §9.2
GND	Chassis case reference ground	-
24VAC2_A 24VAC2_B	Power supply port 2	24VAC +/- 3V 100KHz
24VAC1_A 24VAC1_B	Power supply port 1	24VAC +/- 3V 100KHz
RX1+ / RX1- TX1+ / TX1-	Communication network port 1	RS485
0LS1	Reference ground for communication port 1	-
RX2+ / RX2- TX2+ / TX2-	Communication network port 2	RS485
0LS2	Reference ground for communication port 2	-

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9.4 Diagnostic and Maintenance

9.4.1 Maintenance port

See section1.6.

9.4.2 Set of Led

Led	State	Information
Power	Off	Module powered off
	Red fix	Module powered on - FPGA not configured
	Green fix	Module powered on – FPGA operational
Run	Off	Module powered off
	Red fix	Module not synchronized by the communication network
	Green blink	Module synchronized by the communication network

9.4.3 Safety export requirement

The following elements have to be validated in order to ensure the safety:

- The SATURN safety output must be deactivated (by power off the platform or by command) at least once per year. During the outputs deactivation and activation the system can test and validate the relays.
- After a SATURN parameters modification (time cycle, communication speed, number of agent or others), functional tests has to be done.
- The periodicity of relay preventive maintenance has to be defined according to the mission profile
- The SATURN platform has to be used as defined.

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10 Environmental specifications

10.1 Climatic

Operating temperature	-40°C +70°C (TX class according to the EN50155 standard)
Storage temperature	-40°C +85°C

10.2 EMC

Electrical and mechanical characteristics	EN50155 octobre 2007
Electromagnetic compatibility (EMC)	EN50121-3-2

EMC test	Basic standard	Limits	Levels - values	Criterion
Immunity to electrostatic discharges	EN 61000-4-2	EN50121-3-2	Contact :± 6kV Air :± 8kV	B
Immunity to radiated electromagnetic field	EN 61000-4-3	EN50121-3-2	10 V/m	A
Immunity to electrical fast transient / burst	EN 61000-4-4	EN50121-3-2	± 2 kV (direct and capacitive coupling)	A
Surge immunity	EN50155	EN50121-3-2	± 1.8 kV	A
Immunity to conducted disturbances, induced by radio-frequency fields	EN 61000-4-6	EN50121-3-2	10 Vrms	A
Voltage dips and short interruptions on DC network	EN50155	EN50155	Cf EN50155 § 5.1.1	A

10.3 Mechanical

Mechanical test	Levels and values	Criterion
Protection index	IP30 (when installed), IP20 otherwise	
Shocks	Each axis : 50m/s^2	A
Sinusoidal vibrations EN50155 (ed 1994)	Between 5 and 150 Hz, 20m/s² , 2 hours/axis	A
Random vibrations EN50155 (ed 2001)	Noise random vibrations between 5Hz and 150 Hz Each axis, stress duration: 5h, 7.9m/s²	A

10.4 Fire – smoke

Fire/smoke	NFF 16-101/16-102 category A2 (A1 subject to installation)

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10.5Life span

Life span: 400,000 h at 40°C.

As for any electronic device, product MTBF and life span are greatly affected by the temperature in the vicinity of the product. It is advisable to operate (or store) the product at ambient temperatures of less than 40°C for prolonged intervals. 55°C average during hot period (summer for example) around the product shall be considered as a maximum.
The product is not intended to operate in dripping humidity or in an enclosure where water flows.

10.6MTBF

Board	Computed MTBF (h) IEC62380 version 2004, 40°C
Power supply block	About 600 000h
Gateway	More than 580 000h
4 Digital input module – SIL 2	More than 800 000h
4 Digital output module – SIL 2	More than 800 000h
12 I/O + 4 Outputs – SIL 0	About 700 000h

From experience the real MTBF is roughly twice as the computed MTBF. This MTBF depend on the mission profile.

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10.7Insulations between interfaces (Vrms)

P: Packaging
BT: Battery Train (Power Supply module input)
24VO: 24VAC Output Voltage (Power Supply module output)
24VI: 24VAC input (port 1 and 2)
SL1: Communication network port 1
SL2: Communication network port 2
IC: Identification Chip
MAINT: Maintenance port
ETH: Ethernet link (port 1 and 2)
CAN: CAN Interface (port 1 and 2)
SO2: SIL 2 Outputs (4 channels)
SI2: SIL 2 Inputs (4 channels)
SIO0: SIL0 Inputs/Outputs (12 channels)
SO0: SIL0 Outputs (4 channels)

	P	BT	24VO	24VI	SL1	SL2	IC	MAINT	ETH	CAN	SO2	SI2	SIO0	SO0
P	X	1500	1500	1500	1500	1500	1500	1500	1500	1500	2000	2000	1500	1500
BT		X	1500	-	1500	1500	-	1500	-	-	-	-	-	-
24VO			X	-	1500	1500	-	1500	-	-	-	-	-	-
24VI				1500	1500	1500	1500	1500	1500	1500	2000	2000	1500	1500
SL1					X	1500	1500	0	1500	1500	2000	2000	1500	1500
SL2						X	1500	1500	1500	1500	2000	2000	1500	1500
IC							X	1500	1500	1500	2000	2000	1500	1500
MAINT								X	1500	1500	2000	2000	1500	1500
ETH									1500	1500	2000	2000	1500	1500
CAN										0	2000	2000	1500	1500
SO2											2000	-	-	-
SI2												2000	-	-
SIO0													0	1500
SO0														750

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